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GUIDE TO

Adopting Low- and Zero-Emissions Options for Medium- and Heavy-Duty Fleets

Mobility Futures Lab

TRANSPORTATION ENERGY INSTITUTE

DELPHI

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The Delphi Group
434 Queen St Suite 500
Ottawa, ON, K1R 7V7
Canada

Tel.: (613) 562-2005
Fax: (613) 562-2008
www.delphi.ca

For more information, please contact:

Cara LaRochelle
Director of Sustainable Mobility, Delphi
clarochelle@delphi.ca

Marc Saleh
Lead Consultant, Mobility Futures Lab
msaleh@mobilityfutureslab.ca

John Eichberger, Executive Director,
Transportation Energy Institute
jeichberger@transportationenergy.org

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Glossary Of Terms

Battery Electric Vehicles (BEV)
Fully electric vehicles powered by rechargeable battery packs. These vehicles use electric motors instead of a traditional internal combustion engine (ICE) and do not produce tailpipe emissions, i.e., zero-emission vehicle. Power for BEVs is supplied through external electricity sources (charging station).

Biodiesel
A renewable, biodegradable fuel made from organic mass such as vegetable oils, animal fats, or recycled cooking grease.

Carbon Intensity (CI)
Refers to the amount of carbon dioxide (CO2) emissions per unit of energy or fuel consumed. A lower CI means the fuel or energy source produces fewer greenhouse gases.

Depot Charging
Refers to charging electric vehicles at a central location, such a s fleet's home base or depot. Charging is done when vehicles are not in use (e.g., overnight), allowing for a full charge before daily operations.

En-Route Charging
Refers to charging electric vehicles while they are on the road, typically for vehicles that need to recharge during longer trips to extend their range.

Heavy-Duty Vehicle
In Canada, this refers to vehicles with a gross vehicle weight rating (GVWR) equal to or greater than 11,794 kilograms and includes GVWR classes 7 and 8.

Hydrogen Fuel Cell Electric Vehicles (FCEV)
These vehicles use a fuel cell to convert hydrogen gas into electricity which powers an electric motor. These vehicles produce zero tailpipe emissions, with water vapour produced as the only byproduct.

Hydrogenation Derived Renewable Diesel (HDRD)
A renewable fuel produced by hydrotreating plant oils, animal fats, or waste oils. Chemically, it is nearly identical to petroleum diesel and can be used in existing diesel engines without modification. HDRD reduces life cycle greenhouse gas emissions compared to conventional diesel.

Internal Combustion Engine (ICE)
A type of engine that generates mechanical power via combustion of fossil fuels.

Medium-Duty Vehicle
In Canada, Medium-duty vehicles refer to vehicles with a GVWR between 4,536 kilograms to 11,793 kilograms, and include GVWR classes 3, 4, 5 and 6.

Plug-in Hybrid Vehicle (PHEV)
Vehicles that combine a conventional internal combustion engine with a rechargeable battery that can be charged by plugging into an external power source. PHEVs can operate on electric power alone for a limited range before switching to the internal combustion engine.

Acronyms Used In This Report

BEMHDV ► Battery Electric Medium- and Heavy-Duty Vehicles

BEV ► Battery Electric Vehicle

CI ► Carbon Intensity

DCFC ► Direct Current Fast Charging

FCEMHDV ► Fuel Cell Electric Medium- and Heavy-duty Vehicle

FCEV ► Fuel Cell Electric Vehicle

HDRD ► Hydrogenation-Derived Renewable Diesel

ICE ► Internal Combustion Engine

MHDV ► Medium- and Heavy-Duty Vehicle

PHEV ► Plug-in Hybrid Electric Vehicle

ZEMHDV ► Zero-Emission Medium- and Heavy-Duty Vehicle

ZEV ► Zero-Emission Vehicle

Executive Summary

The development of this Guide to Adopting Low- and Zero-Emissions Options for Medium- and Heavy-Duty Fleets was prepared on behalf of the Canadian Transportation Council (CTC) with funding from Natural Resources Canada (NRCan) through the Zero Emission Vehicle Awareness Initiative (ZEVAI).

The decarbonization of medium- and heavy-duty vehicles (MHDVs) is critical, given that transportation emissions already represent the second largest source of emissions in Canada, and are increasing year over year. This increase is mostly driven by increases from freight-bearing heavy-duty trucks: emissions from these doubled from 1990-2022.[1] With only about 130,000 sales annually in Canada, replacing the 2.6 million MHDVs currently on the road with cleaner alternatives will take time. Given that the lifespan of the vehicles can be 15 years or longer, it is critical that we consider options that can reduce emissions from this existing fleet.

The Guide seeks to arm both private and public fleet owners and operators with the knowledge, resources and tools that they need to identify and implement the emissions reduction options that are right for them. This supports both NRCan's goal of enabling greater adoption of zero-emission vehicles (ZEV) by Canadians in all regions of the country, and CTA's mission which is to provide stakeholders with fact-based research that explores economic and environmentally sustainable solutions for Canadian vehicles and transportation markets to achieve a low-carbon future that all Canadians can benefit from.

1 | https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions.html#transport

The existing availability and future promise of these technologies is highly dependent on vehicle class, type and operational requirements. The Guide provides a flexible roadmap that can be tailored to the requirements of a variety of fleets, vehicle types and use-cases. Whether you are starting from scratch, or considering next steps in your existing decarbonization journey, this guide is for you. It is accompanied by CTC's own **Economic Insight Tool** which helps to support decision-making by providing bespoke analysis for your fleet vehicles.

1. Introduction

The transportation sector is responsible for 22% of Canada's greenhouse gas (GHG) emissions.[2] Medium and heavy-duty on-road vehicles (MHDVs) are responsible for 37% of these, despite only representing 17% of the total number of vehicles on Canadian roads.[3] Despite significant improvements over recent years, MHDV can still be a significant source of health-damaging criteria air contaminant emissions, including nitrogen oxide (NOx) and particulate matter, in particular PM2.5. While there has been much attention paid to decarbonizing passenger vehicles, significant effort is needed to continue to reduce emissions from Canada's MHDV stock.

In the Canadian transportation ecosystem, MHDVs play a critical role in the freight supply chain, serving as one of the primary modes of transporting goods locally, across the country and into the United States. For-hire trucking, private trucking and couriers represent a $48-billion industry in Canada. There are over 650,000 trucks on the road in Canada, about three quarters of which operate in urban areas or for regional hauling. The trucking sector significantly contributes to Canada's economy, accounting for 3.6% of Canada's total GDP and more than 5.2% of Canada's workforce.[4]

2 | Environment and Climate Change Canada (2023) Greenhouse gas emissions [Online]. Available at: https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions.html#transport

3 | Kim, C., Thorn, A., Bhardwaj, C., & McBain, S. (2023) Canada's Pathway to Net-Zero for Medium- and Heavy-Duty Trucks and Buses. Pembina Institute. Available at: https://www.pembina.org/pub/ZeroX2040-pathway-net-zero-mhd-trucks-buses (Accessed: 28 November 2023)

4 | Parliament of Canada (2022) 'Road Transportation: Heavyweight of the Canadian Economy'. Available at: https://lop.parl.ca/staticfiles/PublicWebsite/Home/ResearchPublications/HillStudies/PDF/2022-04-E.pdf

Non-freight related applications of MHDV include passenger- and municipal/utility vehicles. Inter-city buses, urban transit and school buses make up a sizable vehicle inventory, with over 78,000 buses on the road across Canada.[5] Non-freight MHDV include waste and recycling trucks, emergency response vehicles, utility vehicles, and work vehicles.

Transitioning to cleaner MHDVs can make a significant contribution to reducing emissions, improving air quality, and enabling a greener Canadian economy. An increasing number of regions are setting targets for Zero-Emission Vehicle (ZEV) sales and fleet composition for MHDVs. In Canada, the Federal Government, through its 2030 Emissions Reduction Plan (ERP), has set its own targets, including that 35% of total MHDV sales in Canada by 2030 be ZEVs, increasing to 100 % MHDV sales to be ZEVs by 2040 for a subset of vehicle types based on feasibility.[6]

This guide, along with the **Economic Insight Tool**, provides step-by-step guidance, accompanied by detailed information and links to resources to support MHDV fleet owners to navigate the transition to ZEMHDVs - from assessing the options to deploying ZEVs at scale. Both the guide and **calculator** also cover low-emission options including alternative fuels and hybrid vehicles. It should be noted that both this Guide and the accompanying **calculator** are based on well to wheel emissions for the production and tailpipe emissions of the fuels and do not account for the emissions arising from vehicle production.

5 | Statistics Canada (2023) 'Canadian passenger bus and urban transit industries, equipment operated, by industry and type of vehicle' Available at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2310008601

6 | Government of Canada (2022) Canada's 2030 Emissions Reduction Plan - Overview. Available at: https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/emissions-reduction-2030/plan/overview.html

The information is presented in layers for ease of access, based around the following six steps:

- **Foundation Setting:** Begin by assembling a dedicated project team, developing a solid understanding of the options, securing internal financing, and exploring available incentives.
- **Target Setting:** Establish an overall vision or target, supported by more specific goals. Before full-scale deployment, a pilot program is a recommended step to gather real-world data on performance, operational adjustments, and ecosystem needs. This step is helpful in identifying potential challenges and making necessary adjustments.
- **Procurement:** Select and procure new vehicles or modify/ repower existing fleet vehicles and charging/ refueling infrastructure. Plan for charging/ refueling, including a facility assessment to accommodate the necessary infrastructure.
- **Installation:** Complete facility upgrades and install charging/ refueling infrastructure.
- **Training and Deployment:** Implement comprehensive training programs for drivers, maintenance staff, and first responders. Following successful testing and training, deploy the zero-emission vehicles into your fleet operations.
- **Monitoring and Scaling:** Continuously monitor the performance and environmental benefits of the zero-emission fleet. Use insights gained to refine practices, share learnings, and plan for scaling up the zero-emission initiative across the fleet.

Section 2 presents the first layer: a high-level step-by-step roadmap. Each step in the roadmap is linked to an accompanying section containing three additional layers of information: High Level, Tell Me More and Learn More (Tools and Additional Resources).

2.

Decarbonization Roadmap

The transition to low- and zero-emission fleets requires a strategic plan that accommodates the diverse considerations of different vehicle types. Building a roadmap involves not only selecting the right technology for your organization's needs, but also understanding the entire ecosystem around your fleet decisions. From setting foundational goals and targets to planning and implementing the necessary charging or refueling infrastructure, each step needs to be carefully tailored to the fleet's vehicle specifications and operations requirements.

The steps outlined here are based on an assumed end-goal of adoption of zero-emissions vehicle (ZEV) technology. In cases where commercial readiness or economics do not yet support the transition to ZEV, meeting overall fleet decarbonization goals may entail the use of alternative fuels or alternative propulsion options such as hybrids, either as interim or more permanent solutions. These are included in the roadmap.

Each step is linked to a similarly colour-coded section containing more detailed information, instruction and resources.

Table 1: Roadmap

	Foundational Steps	Section
Understand your motivation	Consider what is driving your interest in fleet decarbonization – what you hope to gain and what you are willing to risk. Is decarbonization a target in and of itself, or is it a means to an end? What are your customer's and other stakeholders' expectations of you? This will inform the level of ambition and internal cost-benefit analysis of the options. * This reflection / internal discussion step is not covered in the Guide.	N/A
Understand the options	Develop an understanding of low- and zero-emissions technology and energy options for relevant vehicle classes/ vehicle types, and the associated market landscape.	3
Assess the options	Based on the composition and operational requirements of your fleet, the commercial availability of the various technology and energy options, and the possible emissions reductions, assess which ZEV options are feasible and should be considered. Include fueling or charging infrastructure requirements. Note that current feasibility may be limited to a segment of the fleet, to one location or depot, or to a specific route.	4
Estimate costs	Develop an understanding of the economics of ZEMHDVs. Apply **Economic Insight Tool** (EIT) to estimate costs associated with the ZEV options that you have identified in the previous step. Note that the TCO **calculator** is designed to assess a small-scale one-to-one vehicle replacement pilot deployment. Research additional funding options and available financing if applicable. Consider how new business models and financing options might enable decarbonization plans.	5

	Target Setting	Section
Establish goals	Establish a vision or target for fleet decarbonization and set supporting goals. The vision should speak to the end state that you are seeking to achieve and, as such, represents a longer-term outlook. The goals should be designed as shorter-term milestones that support the longer-term vision. Goals should be specific, measurable, achievable, realistic and time-bound.	6
Plan to achieve initial goals	The initial goals are the ones that you will be focusing on first and will require in-depth planning to achieve. Based on the learnings from the foundational steps, and on the steps outlined below, develop a plan to achieve your initial goals and to establish a strong foundation for longer-term goals and overall targets. This plan should identify key success factors and potential risks to be assessed via pilot testing. It should name all actors, along with associated roles and responsibilities.	6
Design pilot project(s)	Design a pilot with specific metrics to monitor, including maintenance and energy consumption, focusing on factors that vary locally. The goal of the pilot is for you to gain a better understanding of the technology's capabilities beyond the averages and worst-case scenarios provided by the OEMs. The data collected from this pilot will help plan scaling more cost-effectively.	6

	Procurement of Vehicles and Infrastructure	Section
Identify energy supply	For BEVs, connect with utility to assess potential necessary upgrades to electrical infrastructure, cost and timetable to accommodate vehicle charging at a depot. For application conditions where depot charging is not viable, explore the availability of public charging infrastructure.For FCEVs, hydrogen refueling may require installation of fuel storage and refueling infrastructure onsite at an existing facility, depot or yard. Alternatively, it may be possible to access public or shared fueling infrastructure. The same is true in the case of higher than mandated blends of alternative fuels including biodiesel and HDRD.	7
Plan for charging/ refueling infrastructure	Conduct a facility assessment to identify any facility modifications and/or upgrades that will be required to accommodate the new charging/ refueling infrastructure. Identify permitting requirements. In consultation with the utility/ fuel provider and infrastructure provider, determine parameters affecting placement of chargers/ refueling equipment and identify supporting requirements.	8
Select and procure vehicles and charging/ refueling infrastructure	For new vehicles, repowers or vehicle modifications a Request for Information (RFI) or Request for Proposal (RFP) may be used to select and procure vehicles and management services, or you may choose to proceed through your regular procurement channels. An RFI or RFP may be used to select and procure chargers, charge management software for BEVs OR for FCEVs, hydrogen refueling infrastructure. Consider “future proofing” elements, such as: • Modular charging systems that make scaling up easier. • Energy efficiency upgrades or adding clean energy elements, including solar canopies. Consider bundling vehicle and charging/refueling procurement through a turnkey solution, particularly if internal capacity is limited.	9

	Installation	Section
Upgrade facilities if necessary	Complete facility upgrades that were identified to accommodate new electrical infrastructure, vehicle chargers, refueling equipment and/or parking and operating patterns. * This represents implementation of planning completed in an earlier step and is not covered in the Guide.	N/A
Install charging/ refueling infrastructure	Complete installation of vehicle chargers or refueling equipment. * This represents implementation of planning completed in an earlier step and is not covered in the Guide.	N/A
	Training, Testing and Deployment	**Section**
Train	Training is typically required for: • Drivers (basic safety, on/off, plug-in charging, hydrogen refueling, maximizing efficiency) • Mechanics (advanced training, preventive maintenance, troubleshooting, diagnostics) • Facilities management and engineering support • Dispatch and front-office staff (as required based on your operations) • First responders (as needed/requested by local firefighters, police, paramedics, etc.)	10
Test and deploy	Examine and test all new equipment to ensure that it meets the specifications within your contract and procurement order and understand performance in real world conditions. Finalize many of the same steps as an internal combustion vehicle, such as getting insurance and completing inspections. Update standard operating procedures, handbooks, and safety protocols for technology-specific needs. Deploy per pilot testing or strategic fleet plan. * This represents implementation of planning completed in an earlier step and is not covered in the Guide.	N/A
	Monitoring and Scaling	**Section**
Monitor and report on performance and cost	Gather mechanical and telemetric data to monitor performance towards KPI's including operational performance and economics. Use the monitored KPIs to adjust the scaling of your planned deployment, based on lessons learned about the capabilities and technological readiness of both the vehicles and infrastructure.	11
Update roadmap	Incorporate learning from the deployment back into your plan. This is an iterative process that should also account for evolving commercial readiness and cost of ZEV technology options.	11

3. Understand the Options

3.1 Zero-Emissions Options

3.1.1 Battery Electric Vehicles (BEV)

High Level

Battery electric vehicles are equipped with electric motors that draw power from a rechargeable battery pack. A battery management system monitors and controls the performance, health, and safety of the battery pack, ensuring optimal energy efficiency, and safeguarding against potential issues such as overcharging, overheating, and overall degradation.

Over the past decade, significant cost reductions and technological advancements in batteries, along with the introduction of regulations in various jurisdictions, have led to an increase in commercially available BEV models in the MHDV space. In Canada, the initial deployments of this technology have primarily been in public transit and school transportation, with a recent and growing adoption in trucking and vocational applications.

As of 2024, BEV technology is not a viable replacement for all diesel-based applications. Challenges associated with battery electric MHDVs include higher capital costs compared to internal combustion engine (ICE) equivalents, manufacturing constraints impacting delivery times, range limitations, charging times, and the availability of public charging stations. Deployments of BEVs in the MHDV sector can benefit from a feasibility assessment of local operations to evaluate emission reductions, operational, and financial viability. Some considerations for these assessments are detailed in subsequent sections.

Tell Me More

Overall, BEVs have lower operating costs and maintenance costs, and battery electric medium- and heavy-duty vehicles (BEMHDVs) are already cost-competitive with their ICE equivalents, especially in urban delivery applications. These applications typically feature predictable ranges, sufficient daily travel to capitalize on reduced operational costs, and extended downtime that allows fleets to take advantage of low-cost, low-power charging. Existing financial incentives further strengthen the case for electrification in these scenarios, promoting early adoption.[7] As battery costs continue to decrease and production ramps up, it is expected that BEMHDVs will become cost-competitive in more market segments, leading to increased adoption.

As the most mature of the MHDZEV options, BEMHDVs are increasingly commercially available across all but the heaviest vehicle classes and market segments, and this trend is expected to continue. Reductions in battery costs over the past decade have resulted in overall reductions in vehicle costs, and technology improvements have resulted in performance advantages including increased safety and reliability and an improved driver experience.

Challenges associated with BEMHDVs include higher capital costs compared with ICE equivalents, manufacturing constraints impacting delivery times, range limitations, charging times and public charging availability.[8]

7 | NACFE (2018). Guidance Report. Medium-Duty Electric Trucks Cost of Ownership. Retrieved from: https://nacfe.org/research/emerging-technologies/electric-trucks/medium-duty-electric-trucks/#top

8 | Muratori, M., Borlaug, B., Ledna, C., Jadun, P., & Kailas, A. (2023) ‘Road to zero: Research and industry perspectives on zero-emission commercial vehicles’, iScience, 26(5), 106751. ISSN 2589-0042. Available at: https://doi.org/10.1016/j.isci.2023.106751

3.1.2 Hydrogen Fuel Cell Electric Vehicles (FCEV)

High Level

Hydrogen fuel cell electric vehicles (FCEVs) are powered by electric motors, which run on electricity generated by hydrogen fuel cells. In these vehicles, hydrogen gas stored in tanks is fed into a fuel cell stack, where it combines with oxygen from the air to produce electricity. This electricity then powers the vehicle's electric motor. As a result, FCEVs produce zero tailpipe emissions since the only byproduct of the fuel cell reaction is water vapor.

Medium- and heavy-duty fuel cell electric vehicles (FCEMHDVs) are less mature than their battery electric counterparts. Significant investments, particularly in hard-to-electrify applications, such as long-haul trucking, are narrowing the gap in those areas, however. A number of companies are developing heavy duty FCEV trucks for release in 2024/2025 including Daimler and Cummins (collaboration); PACCAR and Toyota (collaboration); Hyundai and Nikola Motors.

While FCEMHDVs do not present the range limitations and fueling time challenges of battery electric vehicles, high capital costs and limited availability of refueling infrastructure are key issues, along with availability of clean hydrogen, and low to zero model availability in many market segments.[9]

9 | Muratori, M., Borlaug, B., Ledna, C., Jadun, P. & Kailas, A. (2023) 'Road to zero: Research and industry perspectives on zero-emission commercial vehicles', iScience, 26(5). Available at: https://www.sciencedirect.com/science/article/pii/S2589004223008283 (Accessed 10 July 2024).

Tell Me More

Hydrogen fuel cell technology has grown as a zero-emission vehicle option due to the ability to produce hydrogen from renewable energy sources and the ability of hydrogen to provide ranges comparable to those of diesel. The most common type of fuel cell for vehicle applications is a Proton Exchange Membrane (PEM) fuel cell. It is comprised of an anode and a cathode, separated by an electrolyte membrane. Oxygen from the air circulates through the cathode at the same time that hydrogen is introduced to the anode. This triggers an electrochemical reaction that generates electricity, which is the vehicle's power source.

FCEMHDV technology is less advanced than that of its BE counterparts, resulting in fewer commercially available models. FCEV technology is seen as particularly promising in long haul Class 8 trucking operations, where BEVs are expected to face challenges due to range and recharging limitations.

Currently, availability of hydrogen is a limiting factor that challenges this technology option. The current lack of clean hydrogen production capacity including limited availability of affordably priced clean hydrogen and lack of distribution networks and infrastructure pose a significant challenge to widescale fleet adoption. Other challenges associated with FCEMHDV adoption include high capital costs, a lack of refueling infrastructure, and restricted model availability across various market segments. As regions across Canada develop their own strategies to build out their clean hydrogen economies the operational and financial viability of FCEMHDV is expected to improve. This development is pivotal as it aligns with global energy trends towards decarbonization and sustainability. Given these challenges today, point to point, return to base, or route specific fleets may be best suited to evaluate FCEMHDV opportunities as infrastructure develops.

3.2 Low-Emissions Options

For use-cases where zero-emissions technologies are not feasible from a cost or operational perspective, and for vehicles currently in operation, alternative solutions for decarbonization include low-emission options such as alternative (renewable) fuels and hybrid technologies. Increased blends of biodiesel or hydrogenation-derived renewable diesel (HDRD) in existing internal combustion engines, plug-in hybrid electric vehicles (PHEV), and hybrid ICE vehicles represent viable alternatives that can provide tangible emissions reductions in the short to medium term.

3.2.1 Biodiesel

High Level

Biodiesel is derived from organic sources such as plant oils (e.g., canola and soy), animal fats, and other organic feedstock from agricultural and forest biomass.[10] Biodiesel is typically blended with petroleum diesel in varying proportions and used to power existing ICEs. This makes it an effective transitional fuel, particularly for market segments that are challenging to decarbonize or where the infrastructure and underlying ecosystem to support decarbonization are not yet well established.

Environmentally, biodiesel has lower overall lifecycle emissions or carbon intensity (CI) than the petroleum diesel it displaces. The CI of biodiesel varies greatly depending on the feedstock and processing.

10 | Veolia North America (2021) 'Biodiesel vs. Renewable Diesel: Are They the Same?'. Available at: https://blog.veolianorthamerica.com/biodiesel-vs.-renewable-diesel-are-they-the-same (Accessed: 30 November 2023).

The CI values of biodiesel fuels registered under the British Columbia Renewable and Low Carbon Fuel Requirements Regulation range from -19.38 to 35.59 gCO2e/MJ, with an average of 11.1 gCO2e/MJ. [11] For comparison, the baseline carbon intensity of diesel is 93 gCO2e/MJ.[12] Note that biodiesel is typically blended, so the actual GHG emissions savings would be reduced according to the blend rate (e.g., a 20% blend of "average" biodiesel with petroleum diesel would have a CI of 77 gCO2e/MJ).

It is worth noting that while biodiesel reduces greenhouse gas emissions compared to petroleum diesel, it does not offer the same level of air quality improvement as zero-emission alternatives like electric or hydrogen fuel cell vehicles. However, incorporating biodiesel into fleet operations does not require significant changes to vehicle technology or refueling infrastructure, making it a good interim solution, particularly for harder-to-decarbonize market segments, and a viable option for vehicles currently in operation. Many provinces already mandate up to 5% blending of biodiesel (B5) into existing fuel supply – the opportunity here is in blending at higher rates. Some adaptations are necessary for higher biodiesel blends (B20 and above), including vehicle engine modifications and changes to fuel handling and storage practices to account for biodiesel's chemical differences from petroleum diesel. In addition, it may be necessary to contact the OEM to assess how using higher blends may impact the vehicle warranty.

11 | Renewable and Low Carbon Fuel Requirements Regulation Approved Carbon Intensities, https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/electricity-alternative-energy/transportation/renewable-low-carbon-fuels/rlcf012_-_approved_carbon_intensities_-_current_20230331.pdf

12 | Clean Fuel Regulations SOR/2022-140, https://laws-lois.justice.gc.ca/eng/regulations/sor-2022-140/FullText.html#:~:text=(3)%20For%20the%20purposes%20of,93%20gCO2e%2FMJ.

Tell Me More

Biodiesel is versatile and suitable for various engines, from buses and trucks to off-road and stationary equipment. It is blended with petroleum diesel and identified by the letter 'B' followed by a number indicating the percentage of biodiesel in the blend (e.g., B20 is 20% biodiesel, 80% petroleum diesel).

Blending offers a practical approach to integrating biodiesel into current fuel infrastructures. Since model year (MY 1994, most MHDV engines have been manufactured to be compatible with biodiesel blends of up to B20 without requiring modifications.

Although most engine manufacturers endorse only blends up to B5 for older engines, research and work from the National Renewable Energy Laboratory (NREL) indicate that blends between B6 – B20 may require only minor or no modifications to engines designed to run on standard petroleum diesel. Research over the last 15 years has shown that sensitive materials such as elastomers and nitrile rubber can withstand B20 blends effectively. For vehicles older than MY 1994, or those designed before the widespread adoption of B20, fleet owners should verify compatibility with biodiesel blends beyond B5, as these engines were not always tested with higher blends. [13] Higher blend biodiesels may be incompatible with some elastomeric materials in those older engines, and they can lead to corrosion of some non-ferrous metals particularly when free water is present. The degradation of such materials can cause operational issues.[14]

13 | NREL Biodiesel Handling and Use Guide (6th Edition) (2023). Available at: https://cleanfuels.org/wp-content/uploads/NREL-Biodiesel-Handling-and-Use-Guide-6th-Edition.pdf (Accessed: 19 September 2024).

14 | Biodiesel (B100) for blending in middle distillate fuels, Canadian General Standards Board, September 2022. https://publications.gc.ca/collections/collection_2022/ongc-cgsb/P29-003-524-2022-eng.pdf

In colder climates, biodiesel requires careful management due to its tendency to gel, which can cause filter plugging.[15] Biodiesel blends higher than B20 must be blended with low cloud-point diesel and include low-temperature flow additives for use in cold temperatures12. This is because some components of biodiesel, including saturated monoglycerides, have been found to separate at temperatures above the cloud point for a biodiesel blend.[16]

With regards to storage and handling, biodiesel has a shorter shelf life and requires additives for long-term storage.

Fleet owners across Canada can expect to encounter different biodiesel pricing strategies influenced by regional regulatory landscapes and market conditions.

3.2.2 Hydrogenation-Derived Renewable Diesel (HDRD)

High Level

Although biodiesel and HDRD have similar feedstocks, their production, availability, and engine behaviour differ.[17] HDRD can be used in higher blends than biodiesel. It can replace petroleum diesel in MHDV internal combustion engines as a drop-in replacement.

15 | Farm Energy (2019) 'Biodiesel Cloud Point and Cold Weather Issues'. Available at: https://farm-energy.extension.org/biodiesel-cloud-point-and-cold-weather-issues/ (Accessed: 12 December 2023).

16 | Canadian General Standards Board (CGSB) (2022): Biodiesel (B100) for blending in middle distillate fuels. Available at: https://publications.gc.ca/site/eng/9.915799/publication.html (Accessed: 10 July 2024).

17 | Natural Resources Canada (2020) 'Biodiesel'. Available at: https://natural-resources.canada.ca/energy-efficiency/transportation-alternative-fuels/alternative-fuels/biofuels/biodiesel/3509 (Accessed: 30 November 2023).

Like biodiesel, the CI of HDRD varies depending on the feedstock and processing. The CI values of HDRD fuels registered under the British Columbia Renewable and Low Carbon Fuel Requirements Regulation range from 12.18 to 44.73 gCO2e/MJ, with an average of 26.3 gCO2e/MJ.[18] Given that HDRD can be used neat, this represents a significant reduction from petroleum diesel. (Note that a 30% blend of “average” HDRD with petroleum diesel would have a CI of 73 gCO2e/MJ).

Tell Me More

HDRD is produced by hydrotreating various oils from products like soybeans and canola, used cooking oil and other similar products, which removes sulphur and other impurities when fatty oils react with hydrogen in the presence of a catalyst at high temperature and pressure. HDRD is nearly chemically identical to petroleum diesel (with the exception of lower to no aromatics, which can require additives) and therefore fully compatible with existing diesel engines and fuelling infrastructure.

It can be used neat but is often blended with petroleum diesel. Similar to biodiesel, it is identified by the letter ‘R’ followed by a number indicating the percentage of HDRD in the blend.

HDRD performs better in cold weather than biodiesel due to its branching molecular structure. It does not ‘gel’ as readily as biodiesel. HDRD’s cloud point can be as low as -40°C. It’s higher cetane number provides better ignition characteristics (shorter ignition delay).

18 | Renewable and Low Carbon Fuel Requirements Regulation Approved Carbon Intensities, https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/electricity-alternative-energy/transportation/renewable-low-carbon-fuels/rlcf012_-_approved_carbon_intensities_-_current_20230331.pdf

Like biodiesel, regional economic and regulatory factors affect the price of HDRD in Canada. It has historically been higher-priced than either petroleum diesel or biodiesel due to supply constraints, coupled with increased demand but this appears to be shifting.

3.2.3 Plug-In Hybrid Electric Vehicles (PHEV) and Hybrid ICE Vehicles (Hybrids)

High Level

Plug-in hybrid electric vehicles (PHEV) and hybrid ICE vehicles (hybrids) combine an electric motor with an internal combustion engine (ICE). The vehicles can switch between or simultaneously use both power sources.

PHEVs have a battery pack that can be charged externally (i.e., plugged in) and a fuel tank that stores traditional petroleum fuels like diesel or gasoline for the ICE. Hybrids primarily use a traditional internal combustion engine as the primary power source and supplement it with a secondary electric motor. The electric motor in hybrid MHDVs is powered by a smaller battery pack which is charged through regenerative braking. This technology captures energy usually lost during braking and converts it into electricity, which is then stored in the battery. This stored energy is used to power the electric motor.[19]

19 | National Academies of Sciences, Engineering, and Medicine (2020) ‘7 Hybrid and Electric Powertrain Technologies’. In: Reducing Fuel Consumption and Greenhouse Gas Emissions of Medium- and Heavy-Duty Vehicles, Phase Two: Final Report. Washington, DC: The National Academies Press. Available at: https://nap.nationalacademies.org/read/25542/chapter/9 (Accessed: 12 December 2023).

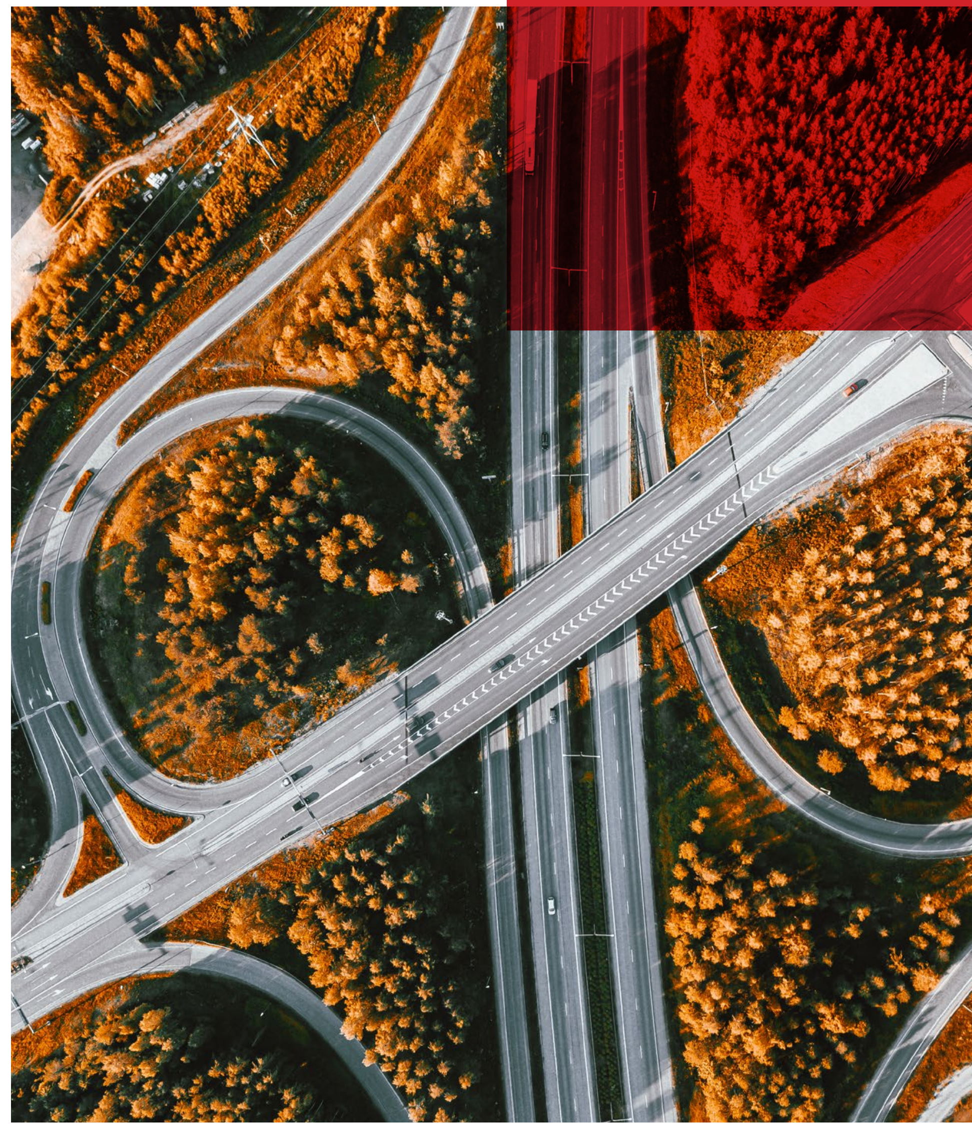
Tell Me More

Both PHEVs and hybrids offer flexible and efficient solutions to reduce GHG emissions. With the progress of BEVs, hybrid and plug-in hybrid electric vehicles (PHEVs) are most viable in urban delivery applications where BEVs' range and charging needs are not yet cost-effective. These hybrid solutions offer an interim option, leveraging regenerative braking technology to improve efficiency.

PHEVs are particularly attractive for two MHDV applications: short-route urban delivery or service applications, and vocational vehicles that travel to a job site and then perform stationary functions. For example, bucket trucks used by electric utility services may travel to a site and operate for hours, where electric power significantly reduces fuel consumption.[20]

Hybrid ICE vehicles are particularly effective in urban delivery contexts, where frequent stopping and starting maximizes the use of regenerative braking. In contrast, long-haul applications, where braking opportunities are limited, offer less potential for regeneration.

20 | National Academies of Sciences, Engineering, and Medicine (2020) '7 Hybrid and Electric Powertrain Technologies'. In: Reducing Fuel Consumption and Greenhouse Gas Emissions of Medium- and Heavy-Duty Vehicles, Phase Two: Final Report. Washington, DC: The National Academies Press. Available at: https://nap.nationalacademies.org/read/25542/chapter/9 (Accessed: 12 December 2023).



LEARN MORE

Tools

- **Natural Resources Canada (NRCan), Electric Charging and Alternative Fuelling Stations Locator**
  This tool helps drivers and operators understand where it is possible to refuel or charge your vehicle across Canada and the US. Filters include searching for charging stations, hydrogen refueling, biodiesel (B20 and above), and HDRD (R20 and above).

Additional Resources

- **Canada's Action Plan for Clean On-Road Transportation**
  Offers information about Canada's strategic plan, acknowledging H2 refueling challenges, and also offers information about official support for retrofits and conversions and intermediate steps.

- **Pembina Institute (2023) Canada's Pathway to Net-Zero for Medium- and Heavy-Duty Trucks and Buses**
  This paper provides a detailed overview and strategic framework for transitioning Canada's medium and heavy-duty vehicle sector to zero-emission vehicles by 2040.

- **NACFE (2020), A Trucking Fleet Primer for Commercial Truck Electrification**
  The North American Council for Freight Efficiency (NACFE) discusses the collaboration between the trucking industry and utilities to facilitate the adoption of electric vehicles, outlines the challenges and opportunities in establishing necessary infrastructure, and offers strategic insights for fleets transitioning to electric vehicles.

- **Hybrid and Electric Powertrain Technologies**
  Chapter excerpt from a larger study on decarbonization options. Realized by the American National Highway Traffic Safety Administration (NHTSA) and the Environmental Protection Agency (EPA).

- **Advanced Biofuels Canada**
  National organization dedicated to promoting the production and use of advanced biofuels across Canada. The organization's focus on policy, sustainability, and industry collaboration makes it an essential guide for those looking to understand and navigate the advanced biofuels landscape in Canada.

- **Renewable Diesel vs Biodiesel For Heavy-Duty Trucks**
  A blog from StarOilco, a Portland, Oregon based Petroleum Company comparison between Biodiesel and HDRD and their uses in heavy-duty trucks. The conclusion of this blog indicates more fleet owners should look more towards HDRD as a reliable fuel for lowering fleet emissions.

- **Biodiesel vs. Renewable Diesel: Are They the Same?**
  Post from Veolia, a global company that specializes in optimized resources management. Information comparing biodiesel vs HDRD.

4. Assess the Options

Fleet owners seeking to decarbonize may elect to move directly from ICE vehicles to ZEVs, or to leverage an interim lower-emissions option such as a hybrid vehicle or higher blends of alternative fuel.

This decision, and the choice(s) of interim and/or ZE technology will depend on a number of factors:

1. Operational viability (e.g., drive cycle analysis, cargo limitations, downtime, climate)
2. Vehicle availability (current and projected)
3. Infrastructure requirements
4. Cost (including availability of incentives) – addressed in **Section 5**
5. Maintenance considerations
6. Impact (GHG reduction potential)
7. Regulatory Landscape

Depending upon the company's goals, the fleet size and composition, the operational profile and geography in which the fleet operates, depot size(s) and location(s) and other characteristics, the relative importance of each of the assessment categories will vary.

Based on the assumption that the ultimate goal is the adoption of ZEV technology, this section will walk fleet owners through the key elements of each of the assessment factors to assess which ZEV option is best suited to their fleet. The assessment will also identify whether that option is currently viable in the context of the fleet and its operations; if not, an interim option that aligns with the longer-term ZEV technology of choice may be selected.

4.1 Operational Viability

MHD fleets span a diversity of applications with varying operational characteristics, including distance travelled, dwell time, and route predictability. Introducing ZEVs first requires a detailed analysis to evaluate which technologies are currently viable within typical fleet operations. Ongoing advancements are expected to extend the viability of all low- and zero-emissions technologies over time.

BEV

Range is a key factor in the operational viability BEMHDVs. This range heavily depends on battery size, which also impacts payload capacity. Larger batteries extend vehicle range but reduce payload due to their weight requirements, presenting a critical trade-off for many fleet operators. Additionally, BEMHDV range is affected by auxiliary power loads, extreme weather, and route conditions. BEV technology benefits from regenerative braking, which allows vehicles to recoup energy in stop-and-go conditions. The combination of daily driving range and available dwell time for charging determines the required charging speed to ensure operational viability for BEVs. Charging stations are available at different power levels, which entail varying charging times. Faster charging stations are more expensive and often require costly upgrades at the deployment site, impacting the financial viability of the project. Therefore, the most cost-effective applications for electrification at this stage involve scenarios where vehicles are parked predictably for extended periods, allowing the use of the lowest charging power/speed.

Fleet operators should refer to the resources provided in this guide and consult with their dealership or OEM to assess the range and payload capabilities of commercially available ZE options.

Depending on your operations and the size of deployment, hiring a consultant to assess your routes, charging infrastructure needs and determine your deployment size based on existing BEV capabilities may be beneficial. Ideally, this would involve deploying pilot applications to assess the capabilities of the technology under local operational conditions.

Public transit and school bus applications of BEVs are growing, with deployments on carefully assessed routes that are highly predictable. The North American Council for Freight Efficiency (NACFE) has published numerous guidance reports analyzing the technological feasibility of BEVs in the trucking industry. These reports suggest that BEVs are a practical solution for Class 3 to 6 vehicles, particularly for urban stop-and-go and regional haul activities, including return-to-base operations and daily travel distances of less than 320 kilometres. However, for heavier truck classes, challenges associated with range and weight restrictions currently prevent battery electric trucks from being a feasible option for routes exceeding 320 kilometres, especially for duty cycles that operate near the maximum allowable weight. These challenges don't preclude BEV's but may limit the use cases or require more trips for a given amount of freight.

FCEV

Hydrogen fuel cell vehicles are anticipated to play a crucial role in long-haul applications where range and weight limitations are critical, overcoming some of the challenges currently presented by battery electric technology. However, these vehicles also face specific weight limitations compared to diesel, primarily due to the weight and size of the required hydrogen tanks. (This issue arises because hydrogen has a significantly lower volumetric energy density compared to diesel).

Additionally, existing Class 8 long-haul trucks in the HFC sector are being designed by OEMs to meet the US trucking industry's 36,287 kg (80,000 lbs) weight limit. In Canada, weight limits can reach up to 54,430 kg (120,000 lbs), which may require vehicle retrofits expected to impact the range of available models.

The U.S. Department of Energy has set goals for heavy-duty trucks to reach fill rates of 8 kg H2/min by 2030 and 10 kg H2/min by 2050, envisioning a six-minute fill time for a 1,200 km range truck. Meanwhile, ongoing research aims to validate proposed fueling standards and equipment. These advancements suggest that hydrogen fuel cell vehicles could achieve fueling times comparable to diesel in the future, providing a significant advantage for long-haul applications where quick refueling is essential.

Alternative Fuels

For operations where ZEVs are not currently technologically viable, interim alternative fuels or hybrid options should be considered. Both are very viable options in most applications.

Biodiesel has a higher cloud point than conventional diesel, meaning it can become thick and gel-like in cold temperatures before temperature will affect petroleum diesel. This gelling can clog fuel filters and lines, hindering engine performance. Fleets should use lower blends of biodiesel in colder months and restrict the usage of higher biodiesel blends in warmer months. Companies specializing in alternative fuels can help fleets establish best practices for this seasonal fuel transition.

Alternatively, companies specializing in conversion kits can help fleet owners convert their existing fleet into dual fuel systems, creating a separation within the vehicle's fuel storage, one for biofuel and one for petroleum diesel.

This small change ensures that the first 30 seconds of start-up uses petroleum diesel to flush the system and create residual heat, allowing the vehicle to then switch to biodiesel without issue.

Similarly, there is a 30-second shut down procedure, where petroleum diesel is again flushed through the system on shut down, ensuring that there is no residual biodiesel fuel that could cause cold start issues.

These are typically not issues for HDRD, which does not need any vehicle modifications to be operationally viable. HDRD has lower cloud and pour points than biodiesel, making it less prone to gelling in cold temperatures. This makes HDRD more similar to petroleum diesel in terms of cold-weather performance.

4.2 Vehicle Availability

The following figures illustrate the relative availability of BEV and FCEV MHDVs. There were 205 BEV models available in November 2023, spread over 10 vehicle types with the greatest availability among MD trucks. There were only 13 FCEV models available at that time, over just 5 vehicle types, close to half being HD trucks. This is reflective of the relative nascency of FCEV technology as compared with battery electric. Note that this is based on U.S. data and may not be reflective of Canadian availability of ZEV models. While the following figures represent the availability of BEV (Figure 1) and FCEV (Figure 2) MHDV in North America, not all of the vehicles represented in the figures are actually available in Canada. (Credit for figures: ZETI Data Explorer Tool.)

This is an evolving landscape, as evidenced by the significant growth from 2021 to 2023 illustrated in these figures, so Guide users are encouraged to consult the ZETI Data Explorer Tool[21] for updated statistics.

21 | Global Drive to Zero (2023) 'ZETI Data Explorer'. Available at: https://globaldrivetozero.org/tools/zeti-data-explorer/ (Accessed: 4 March 2024).

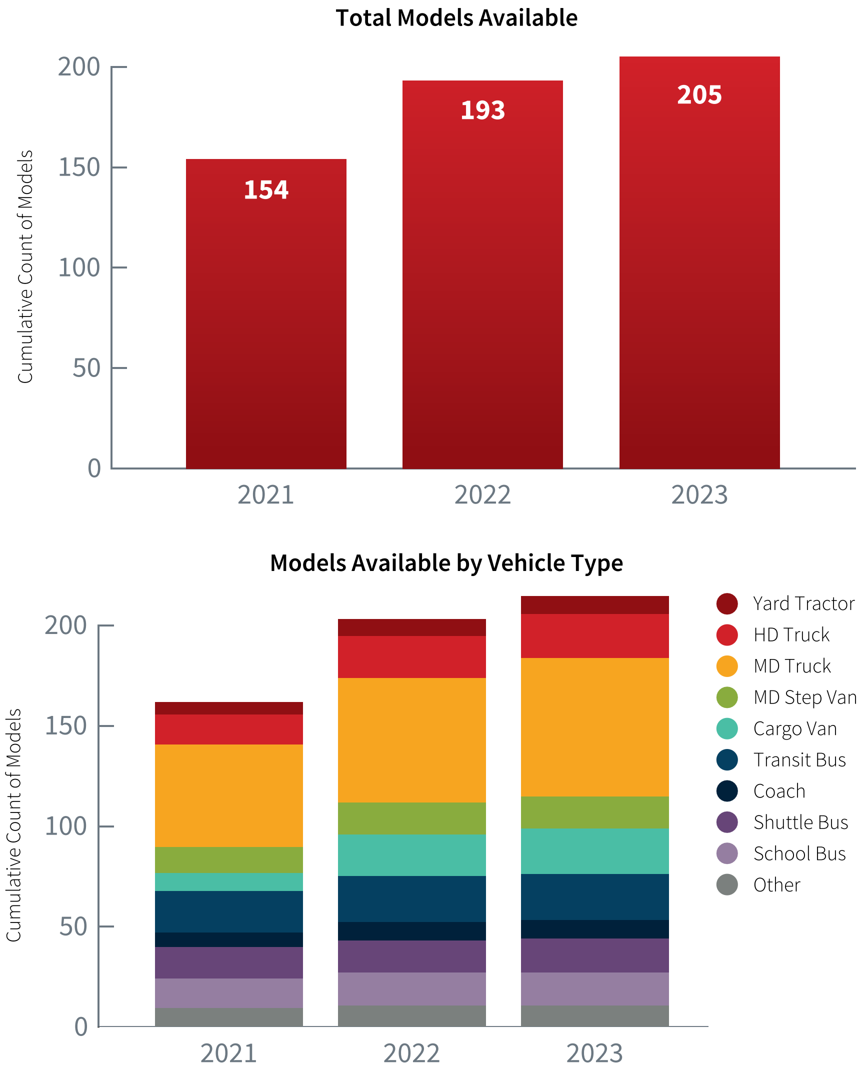


Figure 1: Availability of BEMHDV models in North America

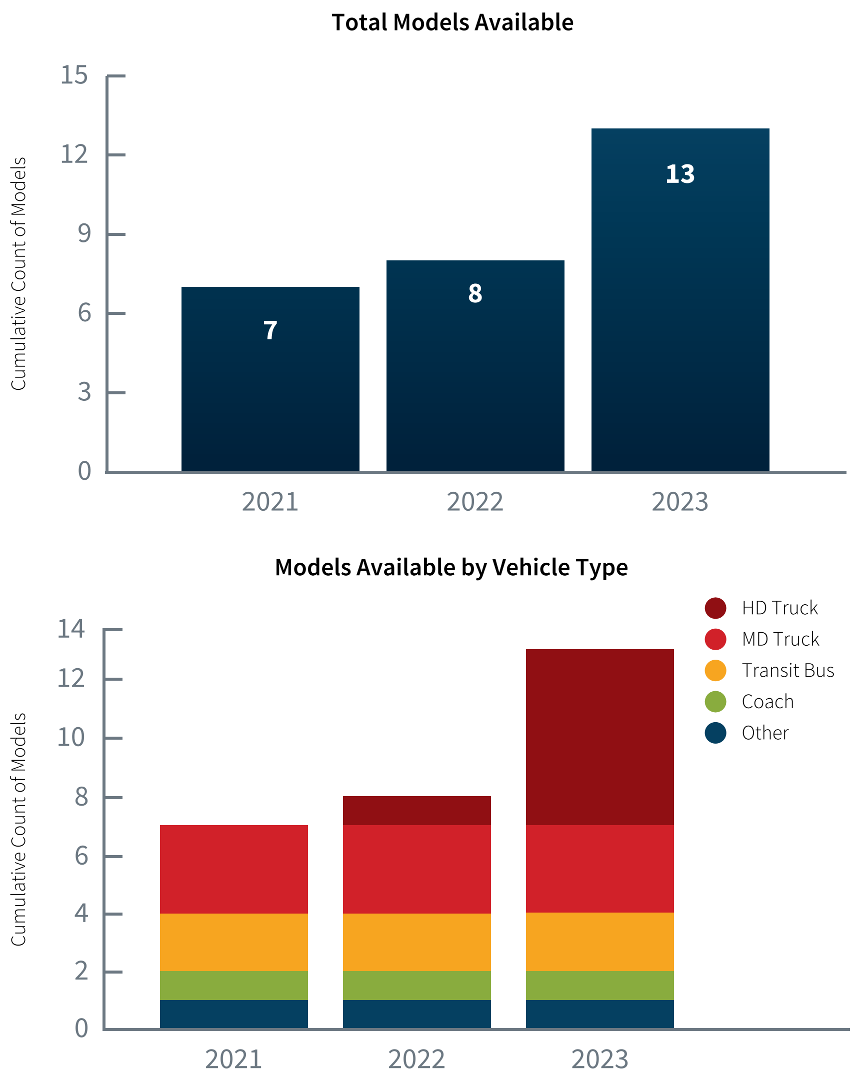


Figure 2: Availability of FCEMHDV models in North America

4.3 Infrastructure Requirements

This section addresses on-site charging and re-fueling requirements. More detailed information on infrastructure installation is available in **Section 8**. For information on public charging and fueling facilities in Canada, the Natural Resources Canada (NRCan) Electric Charging and Alternative Fuelling Stations Locator[22] is a useful resource.

4.3.1 BEV Charging

The deployment of BEV technology typically necessitates the installation of charging infrastructure at the depot, and possibly in other locations. For ranges under about 300 km, depot charging is typically sufficient. Opportunity charging – for example while loading and unloading, can provide additional power where required for longer routes. Public en-route charging is typically only required for long-haul applications. However, depending on the drive cycles, parking locations of MHDVs, and the cost of deploying charging infrastructure at a depot, public charging infrastructure may become necessary for a wider range of applications, particularly for unpredictable routes or when drivers keep the vehicle with them, reducing returns to a centralized depot.

The power level of charging infrastructure dictates the possible rate of recharge (the actual rate of power received by the vehicle is determined primarily by the configuration of the vehicle, the state of charge and temperature of its battery), which also is largely determined by the vehicle's duty cycle, size of the battery and recharge session dwell time.

22 | https://natural-resources.canada.ca/energy-efficiency/transportation-alternative-fuels/electric-charging-alternative-fuelling-stationslocator-map/20487#/find/nearest?fuel=HY

Charging solutions vary in power levels, commonly referred to as Level 2 and Level 3, or Direct Current Fast Charging (DCFC). Figure 3 outlines the typical charging power required for each of these three charging scenarios.[23]

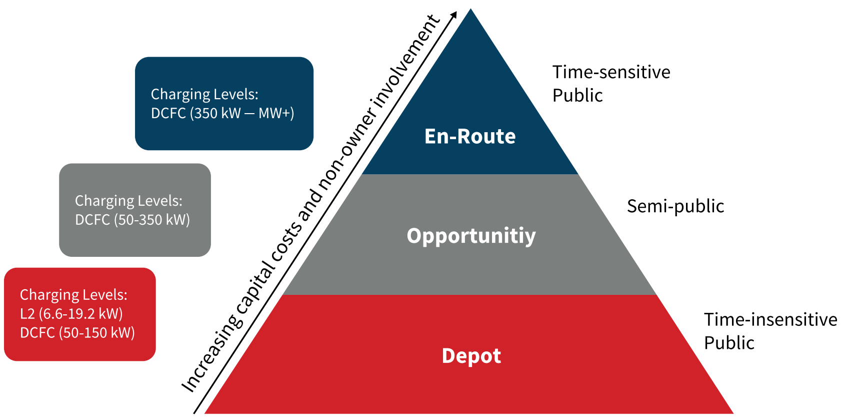


Figure 3: Charging power requirements by use-case

For vehicles with smaller batteries and longer dwell times, such as those traveling short distances daily, low-power chargers (9-19 kW, Level 2 AC) at depots may suffice. Applications involving higher daily distances with larger batteries or more limited dwell times for charging typically require higher-power chargers (50-350 kW, Level 3 DC). The heaviest long haul trucking vehicles with longer range will require chargers of 1 MW or greater. The use of higher power chargers and the scaling of a BEV deployment may require upgrading the facility's electrical grid connection and/or integrating stationary battery storage to optimize the use of a lower grid capacity.

23 | Perspectives on Charging Medium- and Heavy-Duty Electric Vehicles, Muratori and Borlaug, NREL, 2021. https://www.nrel.gov/docs/fy22osti/81656.pdf

Sections 7.1 and **8.1** respectively delve into the specifics of connecting with local electrical utilities to understand their rate structure and timelines, and determining charging infrastructure needs.

As of 2024, relying entirely on public charging infrastructure to charge BEMHDVs is not feasible in most regions. Electrical utilities in certain jurisdictions are, however, exploring participating in infrastructure development specifically for MHDVs. Public charging infrastructure will be particularly critical for long haul trucking applications on freight corridors. The charging power for the long-haul sector is anticipated to include a new MCS (Megawatt Charging Standard) that is nearly complete, aiming to provide a power level of 1000-3700 kW to enable charging speeds comparable to refueling diesel vehicles.

CASE STUDY

Electrifying School Buses on Prince Edward Island

When it comes to early adoption of innovative technologies, many of us think that we should leave it to the big guns to be the trailblazers. Not PEI. Canada's smallest province is also home to the largest fleet of electric school buses (ESBs) in Canada.

The Province purchased its first 12 Canadian-made Lion Electric ESBs in 2020. Four years later, they are up to 107, or 30 percent of the fleet. That number is steadily increasing, thanks to a commitment from Premier Dennis King's government to fully electrify PEI's school bus fleet by 2030.

Driving Change in PEI

In May 2020, Premier King announced that PEI is "committed to moving our school buses to full electrification over the next few years and leading the country in this form of clean transit." Along with this ambitious commitment came a clear mandate from the government, including the budget to support it.

By Investing in ESBs, the Province is supporting Island children in being part of the shift to a cleaner, more sustainable province. Each ESB reduces greenhouse gas emissions by 23 tonnes compared to a standard diesel bus - equivalent to taking five cars off the road. Further, ESBs are healthier and safer for children who are at higher risk when exposed to diesel exhaust, which contains harmful particulate matter and air pollutants that can contribute to respiratory illnesses.

While ESBs are cheaper to fuel and maintain over the longer term, they come with a much higher capital cost (the full sized, 72-seat buses cost $400,000 each.) A centralized ownership structure has helped to simplify the planning, funding, and procurement processes, which has in turn facilitated the fleet conversion: through the Department of Education and Early Years, the provincial government procures and owns the buses, which are managed by the Public Schools Branch and the French Language School Board. The Province has accessed federal funding programs and is covering the balance of the cost of both the buses and charging infrastructure. This financial support has been fundamental to the success of the initiative.[24]

Decentralized Charging Requirements

With over a hundred buses spread across the 5,660 km2 province, conveniently located charging infrastructure is critical, but challenging. Currently, the province has 49 chargers installed at the homes of drivers on rural routes who have traditionally parked their buses at home. These are supplemented by 58 Level 2 chargers at three central locations (two depots plus one high school), and an additional 17 chargers located at the maintenance depots. Installation of two level 2 chargers is planned at each of the other 13 high schools across the province.

24 | P.E.I.'s Electric School Bus Build-Up: Lessons from one of Canada's Leading Jurisdictions. Conservation Council of New Brunswick. https://www.conservationcouncil.ca/wp-content/uploads/2022/08/PEI-bus-Fact-Sheet-E-1.pdf

CASE STUDY

This approach has yielded overall cost savings compared to a fully central depot charging model and is more readily accepted by the drivers. When faced with driver turnover, it is relatively inexpensive ($500 to $1000) to move a charger.

In addition to its Level 2 chargers, the Province is planning to install a Level 3 charger at every high school. This will extend the range of buses, allowing them to be used for extra curricular and after-hours activities when required. This will allow PEI to continue to maximize the benefits of Level 2 charging, including reduced capital and usage costs, extended battery life and less demands on the energy grid, while leveraging the convenience of faster Level 3 charging when it is most needed.

Lessons Learned as Early Adopters

Range

There are two rated range options when purchasing buses: 150 km and 200 km per charge. (Note that actual ranges tend to be lower than this.) For the first buses they selected the former option, but have subsequently purchased only the longer-range buses. This difference in range between buses in the fleet has necessitated strategic deployment based on route length and characteristics: shorter-range buses are primarily reserved for urban routes, and the longer-range buses are used on the longer rural routes. In more recent procurements, the Province has opted to maximize range. This has allowed for buses to be interchangeable by location.

Winter Weather

ESBs offer some unique advantages in winter weather: because battery weight is distributed evenly between the wheels, driving in the snow can be less challenging that in a front-heavy diesel bus. There are challenges as well, however.
The buses use diesel powered heaters, so cold temperatures have had a negligible impact on range (without them, the range could be reduced by as much as 40%). There were issues with the heaters on some buses, which led not just to uncomfortably cold interiors, but also fogged up windows, meaning that these buses had to be removed from use in most cases. Lion Electric, the bus manufacturer, in cooperation with its diesel heater manufacturer, did come up with a solution which is now being implemented, but the issue led to considerable driver frustration.

The following statement issued by the Province confirms that PEI is still committed to ESB electrification despite the challenges that have come with being an early adopter:

> *The Government of PEI is committed to reducing greenhouse gas emissions, to building resiliency to the impacts of climate change, and to becoming the first net-zero province. Transportation is the largest source of greenhouse gas emissions in PEI, accounting for 46% of total emissions in 2022. The transportation sector has the greatest potential for significant emissions reduction in the short and medium term.*
>
> *PEI is on track to having a full EV school bus fleet by 2030. The Department of Education and Early Years has purchased 107 new electric school buses over the last four years. Additional EV school buses will be regularly added to the fleet to meet the 2030 goal.*

4.3.2 FCEV Refueling

In Canada, while hydrogen supply is abundant, hydrogen refueling infrastructure is currently limited, mainly serving private fleets in the light-duty or public transit sectors, with only scattered stations nationwide. This current lack of infrastructure poses a significant barrier to hydrogen truck pilots. Existing pilot programs have relied on mobile hydrogen refueling solutions, which result in higher costs and slower refueling times. Starting in 2025, several fuel providers plan to construct stations along specific corridors with support from federal funding. **Section 8.2** expands on the considerations of assessing refueling needs.

While BEV technology is expected to be installed at depots for various applications, hydrogen fuelling infrastructure is primarily only installed at depots for public transit applications and large operators in the Class 8 regional haul space. The remaining infrastructure is expected to be developed along long-haul corridors to serve Class 8 long-haul trucks. Hydrogen refueling infrastructure varies in refueling speeds, and there is significant ongoing research and development aimed at expanding hydrogen refueling stations.

4.3.3 Alternative Fuels

The infrastructure for biodiesel and HDRD involves storage and fueling facilities. These fuels typically use similar storage and dispensing systems as petroleum diesel, generally necessitating the use of a UL listed storage tank and some type of secondary containment system. Neat biodiesel requires separate storage tanks, unlike HDRD. Depending on the specific needs and circumstance of the fleet, some fleets owners and operators may choose to have fuels delivered preblended, while others may choose to blend fuels onsite.

Biodiesel can be more prone to gelling in cold temperatures, so infrastructure in colder regions may need additional features like heated storage tanks or blending facilities to mix biodiesel with petroleum diesel in winter months. Conversely, HDRD and can be stored and used in the same way as petroleum diesel.

4.4 Cost

Understanding the costs associated with deploying alternative powertrain vehicles requires a detailed, market-segment-specific, and region-specific analysis. An in-depth examination of costs is provided in **Section 5** of this report. In addition, an **Economic Insight tool** is available on the CTC's website to support fleet operators in estimating overall costs and comparing options.

4.5 Maintenance Considerations

High Level

Maintenance requirements for BEVs and FCEVs are expected to be reduced as compared to their ICE counterparts, as there are fewer moving parts. However, the charging infrastructure itself will require regular maintenance to ensure optimal performance, reliability, and longevity. A number of business models have been developed around providing maintenance services for charging stations, offering solutions such as routine inspections, software updates, and on-site repairs to ensure high uptime and efficiency, particularly as the deployment of higher-power chargers increases.

Additional maintenance requirements are a consideration for alternative fuels, specifically for biodiesel. Given that maintenance considerations differ depending on the specific fuel used, fleet operators should ensure that drivers and maintenance crews are clearly informed of which fuel (and at which blend) a vehicle is using.

Tell Me More

4.5.1 Biodiesel Maintenance Considerations

Strong Solvent Properties: When used in high blending rates, biodiesel can act as a solvent that can dissolve varnish and sediments in fuel tanks and systems. When transitioning from diesel to B20, fleets typically employ a shorter fuel filter change interval for one or two maintenance cycles. Normal intervals are then resumed. Temporary or occasional diesel use does not require any change to normal maintenance intervals.

Material Compatibility: Biodiesel can degrade certain materials like hoses, gaskets, and seals. Components made from polypropylene, polyvinyl, and some types of nitrile rubber are particularly susceptible. Biodiesel has also been found to be degrade copper-based materials including bronze and brass.[25] Therefore, it's important to ensure that all parts of your operations' fuel system are compatible with biodiesel, especially when using higher blend rates. Materials such as Teflon, Viton, and nylon are recommended as good, resistant alternatives. Biodiesel blends up to 20% (B20) can be used in unmodified diesel engines and generally require minimal changes to existing fueling infrastructure. However, it is important to note that B20 blends may not be suitable for engines manufactured before 1994. These older engines include components incorporating certain elastomers that can soften and degrade when exposed to higher concentrations of biodiesel. Since 1994, engines have been equipped with materials compatible with B20, enhancing their resilience to biodiesel's solvent properties. Nonetheless, regular checks and maintenance of these components are needed when using higher-concentration biodiesel blends (greater than B20).

Cold Weather Issues: Biodiesel has a higher gel point than petroleum diesel, which can lead to challenges in many parts of Canada. Fleet operators should consider heated storage and fuel lines to prevent gelling. The gel point varies with the biodiesel blend percentage, so specific temperature management strategies may be needed depending on the biodiesel and season.

4.5.2 HDRD Maintenance Considerations

Similarity to Petroleum Diesel: HDRD typically does not require specialized equipment and can use existing diesel infrastructure.

4.6 Impact

The transition to ZEMHDVs leads to varying environmental and air quality impacts, contingent on the fuel's production method and the fleet's location. The **Economic Insight Tool** associated with this guide provides operational emission reductions associated with a deployment based on best available data from individual provinces.

4.6.1 BEV Impacts

The environmental benefits of BEVs are closely linked to the carbon intensity of the local electricity grid used for charging. In regions where the grid relies on cleaner energy sources, such as renewables and nuclear, BEVs can achieve lower or nearly zero lifecycle emissions.

25 | M.A. Fazal, A.S.M.A. Haseeb, H.H. Masjuki, Corrosion mechanism of copper in palm biodiesel. (2013). Available at: https://www.sciencedirect.com/science/article/pii/S0010938X12004891 Accessed 23 September 2024.

Conversely, in areas dominated by coal or petroleum-fuel-based grids, the emissions from BEVs while still significantly lower than their gas and diesel counterparts, will see their biggest emissions reduction benefits over time as the grid continues to improve it's carbon intensity. Although Canadian provinces vary in the emission intensity of their grids, Canada overall boasts one of the cleanest electricity grids globally.

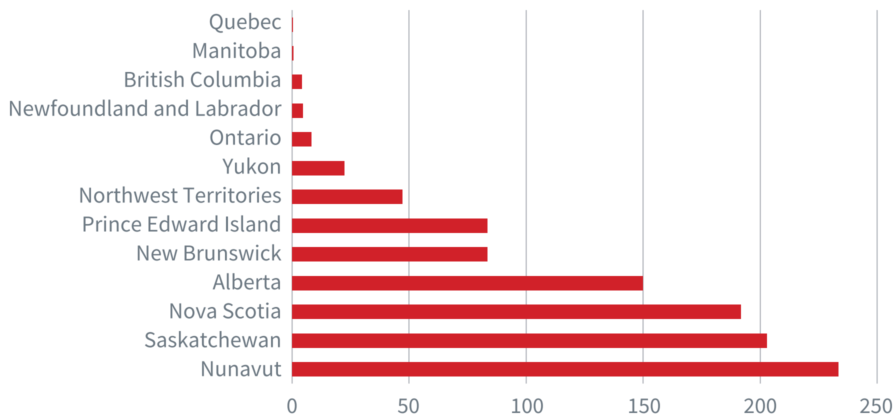


Figure 5: Electricity Grid Carbon Intensity (CO_2e/MJ) by Province/Territory (May 2024)[26]

4.6.2 FCEV Impacts

The environmental impact of FCEVs largely depends on the method of hydrogen production. While hydrogen is a colourless gas, the popular naming convention has assigned different colours to distinguish between production methods. Figure 5 outlines all the options, but the most common are green, grey and blue hydrogen.

Green hydrogen, produced via electrolysis of water using renewable energy sources, offers the most significant emission reductions but is currently limited in production and is the costliest of the options. Grey hydrogen is produced from natural gas using steam methane reforming. Blue hydrogen is as well; however, it adds carbon capture and storage to reduce the net processing emissions.

26 | Environment and Climate Change Canada (ECCC) (2024): Emission factors and reference values. Available at: https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/output-based-pricing-system/federal-greenhouse-gas-offset-system/emission-factors-reference-values.html#fn20 (Accessed 10 July 2024.)

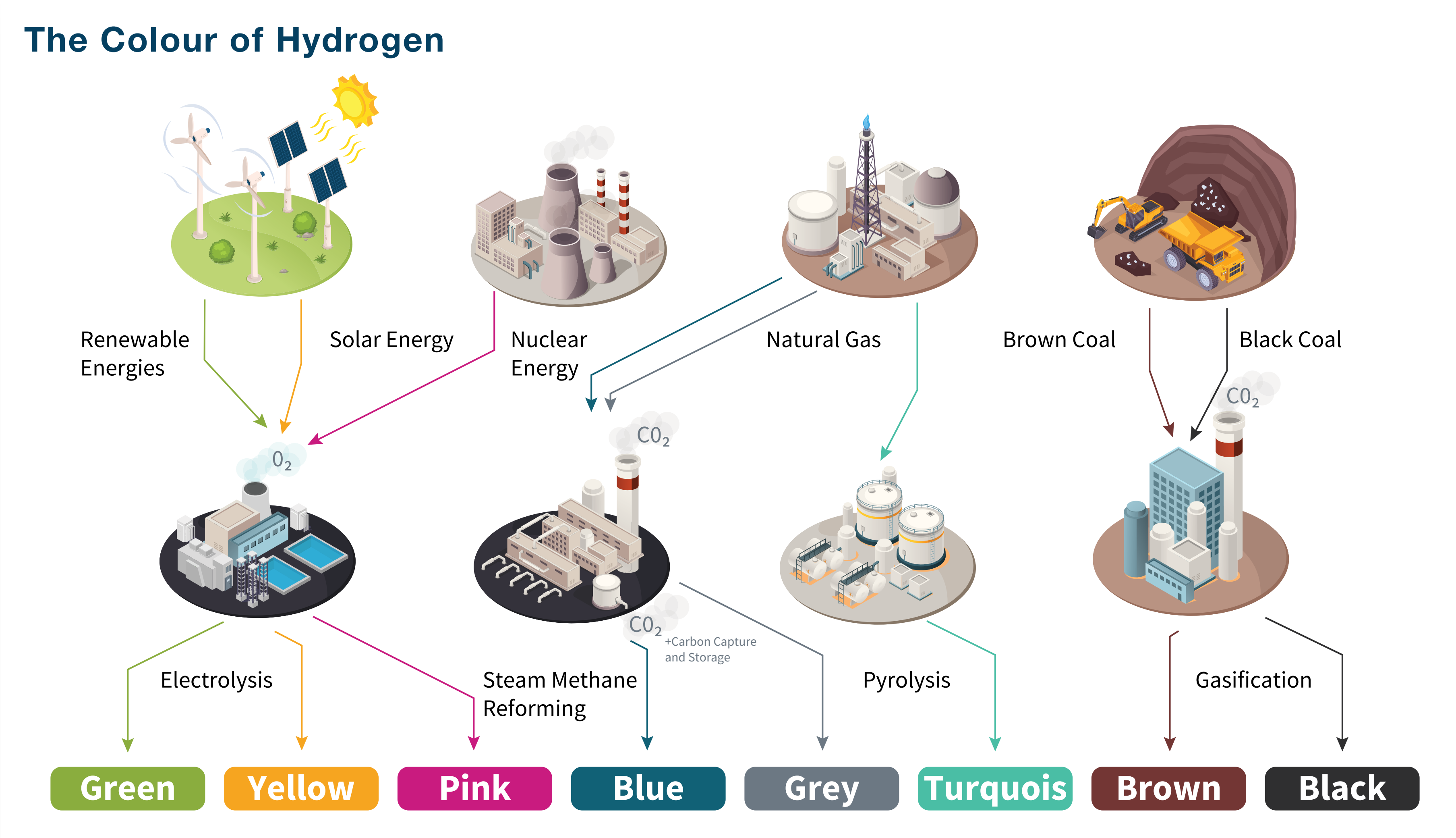


Figure 6: Types of Hydrogen[27]

27 | https://icograms.com/templates/infographics/hydrogen-production

4.6.3 Alternative Fuel Impacts

The use of biodiesel and HDRD also offer substantial reductions in GHG emissions compared to petroleum diesel, though the exact reduction levels depend on the feedstocks and production processes used. Note that the use of B100 is unlikely, as biodiesel is more often used in lower blends (up to B20), so actual GHG emissions reductions would be based on blend rate.

Figure 7 shows the lifecycle emissions of different samples of biodiesel and HDRD compared with diesel.

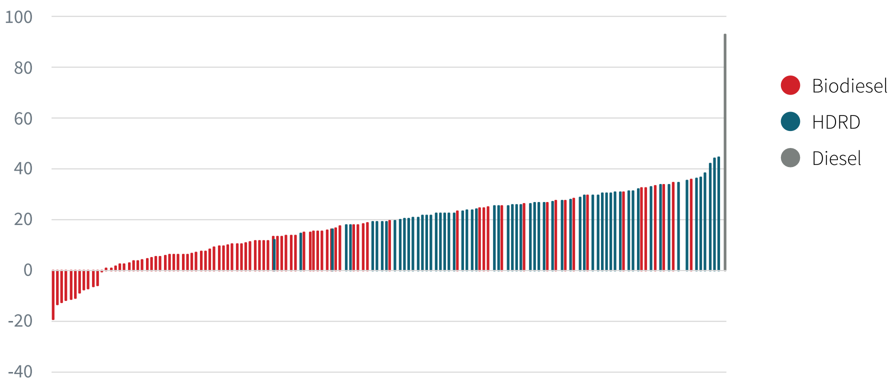


Figure 7 Lifecycle Emissions by Fuel Type (g CO_2e/MJ)[28]

Compared to petroleum diesel, both fuels lead to lower levels of the criteria air contaminants that are harmful to human health, including particulate matter, carbon monoxide, and unburned hydrocarbons. Some studies indicate possible small increases in nitrogen oxides from biodiesel but vary considerably from study to study.[29]

28 | CI values from British Columbia Renewable and Low Carbon Fuel Requirements Regulation Approved Carbon Intensities, https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/electricity-alternative-energy/transportation/renewable-low-carbon-fuels/rlcf012_-_approved_carbon_intensities_-_current_20230331.pdf

29 | University of Toronto, 2019 https://www.toronto.ca/legdocs/mmis/2019/ie/bgrd/backgroundfile-130965.pdf

4.7 Regulatory Landscape

The federal government and some provincial governments are leveraging regulation to accelerate the adoption of low and zero emission MHDVs. As a fleet operator, this may influence the selection of low-carbon vehicle technology, and/or where vehicles are deployed.

Federal ZEMHDV Sales Targets

Canada has committed internationally to 30% of sales of new medium and heavy-duty truck and bus fleets being zero-emission by 2030; and 100% zero-emission by 2040 by signing the Global Commercial Drive to Zero Memorandum of Understanding, alongside many other countries.[30]

ZEMHDV Regulatory Measures

Please refer to Appendix A for a list of federal and provincial policies and regulations relating to the decarbonization of MHDV. The most salient of these are described here.

Provincial Initiatives

At the provincial level, British Columbia and Quebec are leading in the development of clean regulations and sales targets for ZEMHDVs. It should be noted that the Province of Quebec is working with seventeen U.S. states and the District of Columbia through the Multi-State Zero Emission Vehicle (ZEV) Task Force, a coalition facilitated by NESCAUM (Northeast States for Coordinated Air Use Management), to produce a bold Action Plan for accelerating a transition to zero-emission trucks and buses.[31]

30 | CALSTART Global MOU on Zero-Emission Medium and Heavy-Duty Vehicles https://globaldrivetozero.org/mou-nations/

31 | NESCAUM (2022) 'Multi-State Medium- and Heavy-Duty Zero Emission Vehicle Action Plan'. Available at: https://www-f.nescaum.org/documents/multi-state-medium-and-heavy-duty-zero-emission-vehicle-action-plan/ (Accessed: 18 January 2024).

LEARN MORE

Tools

- **The Zero-Emission Technology Inventory (ZETI)**
  This tool is a searchable compendium of MHDZEV's available in the U.S. and Canada, and around the world. Developed by CALSTART, users can filter by location (country/ continent), ZEV technology type, vehicle type, manufacturer and model. Further, projected availability can be searched for up to two years in the future. Commercial availability is defined as availability for immediate production based on placed orders. *Fleet owners are reminded that this may not be reflective of availability in Canada in all cases.

- **Transport Canada's iMHZEV - Eligible Vehicles**
  A searchable database provides a useful way to "double check" availability of MHDZEV makes and models in the Canadian context.

- **Electric Autonomy EV Listings**
  Every light- and medium-duty electric vehicle currently available to order in Canada

- **Clean Energy Canada and CALSTART (2024) Zero Emission Medium- and Heavy-Duty Vehicle (ZEMHDV) Canadian Model Availability Catalogue**
  Clean Energy Canada developed a version of the CALSTART's ZETI tool tailored for the Canadian context identifying commercially available ZEMHDVs.

Additional Resources

- **Road to Zero Research and Industry Perspectives on Zero-Emission Commercial Vehicles**
  A comprehensive overview from research (National Renewable Energy Laboratory) and industry (Volvo Group North America) on ZEMDHVs.

- **NACFE (2023), Messy Middle, A Time for Action**
  NACFE explored the myriad powertrain options available to fleets in fleet operations. The report contains the analysis of benefits and challenges of each option and lays out the factors fleet managers need to consider when deciding which technologies to deploy in their operations.

- **NACFE (2019), Amping Up, Charging Infrastructure for Electric Trucks**
  Highlights the key factors influencing charging infrastructure planning decisions for commercial BEVs.

- **Environment and Climate Change Canada (2022) What are the Clean Fuel Regulations**
  The Clean Fuel Regulations incentivize the development and adoption of cleaner fuels, technologies, and processes in Canada, aiming to reduce the carbon intensity of fuels like gasoline and diesel, which will decrease by approximately 15% by 2030 compared to 2016 levels.

LEARN MORE

- **Transport Canada (2022) Incentives for Medium- and Heavy-Duty Zero-Emission Vehicles**
  The Canadian government's iMHZEV Program, launched in July 2022, provides incentives of up to $200,000 to promote the adoption of zero-emission vehicles in medium and heavy-duty vehicle categories, facilitating a transition to a low-carbon transportation sector.

- **Government of British Columbia (2023) B.C. Medium- and Heavy-Duty Zero-Emission Vehicles**
  2023 Consultation Paper: The Province of British Columbia, recognizing the substantial contribution of medium and heavy-duty (MHD) vehicles to its transportation sector emissions, has committed to stringent zero-emission vehicle (ZEV) targets. These include regulated sales mandates aligning with global leaders like California, aiming for 100% ZEV sales by 2040, with an interim target of 30% by 2030.

- **Natural Resources Canada (2023) Green Freight Program**
  A funding program managed by Natural Resources Canada aims to support the deployment of green technologies and practices and improving fuel efficiency across the freight sector.

- **Transport Canada (2022) Canada's Action Plan for Clean On-Road Transportation**
  A strategic document by Transport Canada, outlining initiatives and measures to promote clean and sustainable road transportation in Canada. It details government investments in infrastructure, such as charging stations, and regulatory measures aimed at increasing the sales of ZEVs to meet stringent environmental targets by 2035.

5. Estimate Costs

Understanding the costs associated with deploying alternative powertrain vehicles requires a detailed, market-segment-specific, and region-specific analysis. An **Economic Insight tool** is available on the CTA's website to support fleet operators in estimating overall costs and comparing options.

5.1 Powertrain Economics

5.1.1 BEV Economics

For BEMHDVs, higher capital costs are typically offset by lower operational expenses for charging and maintenance over the vehicle's lifetime. Prices of BEMHDVs are expected to continue coming down due to improvements in battery technology and evolving regulations that are leading to increased production volumes.

Electricity pricing for charging can vary across jurisdictions depending on the utility rate structure. Charging costs are typically measured in kilowatt-hours (kWh), and some jurisdictions offer time-of-use pricing, where electricity is cheaper during off-peak hours when the utility has excess capacity. In addition to the cost of electricity consumed in kWh, utilities often charge a monthly fee called a demand charge. This fee is based on the highest power load (in kW) consumed during any 15-minute interval in the month.

The demand charge incentivizes consumers to stagger their power consumption to avoid peak loads. For electric vehicle fleets, this means it is cost-effective to spread charging throughout the day rather than charging all vehicles simultaneously over a short period using high-power chargers.

In other words, fleet owners can minimize costs by charging at lower power levels, which reduces both operational costs (via a lower demand charge) and capital costs (by lowering the expense of charging stations and grid upgrades).

The **Economic Insight Tool** allows users to select the number of chargers at different power levels required for deployment, as well as the costs of charger installation and any necessary grid upgrades.

As of 2024, financial incentives are crucial to making BE technology economically viable for most MHDV applications, especially in large deployments requiring significant grid upgrades. In Canada, operators can access both federal and provincial incentives, where available. This financial support can greatly reduce the costs associated with vehicle purchases and the deployment of charging infrastructure.

Depending on the MHDV application, incentive programs, and the regulatory structure of local utilities, fleets can determine what portion of grid upgrades they are financially responsible for. These upgrade costs can vary significantly between jurisdictions, necessitating a thorough assessment by fleet operators. This topic is explored in greater detail in **Section 8**.

5.1.2 FCEV Economics

FCEMHDVs currently face higher capital costs compared to BEVs due to the early stage of fuel cell technology and lower production volumes. However, these costs are expected to decrease as the technology advances and economies of scale are realized, following a trajectory similar to BEVs.

Hydrogen fuel, particularly green hydrogen produced from renewable sources, remains too expensive to compete with diesel at present, but production costs are expected to decline as investment in hydrogen infrastructure and technology improves. While Canada has not set cost targets for hydrogen, the United States is aiming to reduce the cost of clean hydrogen to $1 per kilogram within a decade (it is currently over $14.00 per kg. [32]) Some provinces play a larger role in hydrogen production than others, but pump prices will vary based on the type of hydrogen produced (e.g., green, blue, or grey) and the costs set by distribution companies. The **Economic Insight Tool** uses default average costs from the limited number of public hydrogen stations in Canada to estimate fleet fuel costs, though actual prices may differ regionally.

Similar to how BEV fleets manage electricity costs, FCEMHDV operators must assess local hydrogen pricing and availability. Federal and provincial incentives are also available to help reduce both vehicle acquisition costs and the expenses related to refueling infrastructure, improving the feasibility of FCEMHDVs for pilot projects and larger-scale operations. For fleets that install depot refueling infrastructure, the **Economic Insight Tool** allows users to input the total costs. Incentives and subsidies can help limit these infrastructure costs. This topic is explored further in **Section 8.2**.

5.1.3 Biodiesel and Renewable Diesel Economics

The cost of vehicles using biodiesel (B20) and renewable diesel (R99) is generally the same as for those running on conventional diesel. The key difference in overall economics comes from the cost of the fuel itself, which can vary based on several factors.

First, the price of feedstocks—such as soybean oil, canola oil, and animal fats—directly impacts the cost of producing biodiesel and renewable diesel. Additionally, production and distribution costs play a role, as regional production capacity and transportation logistics affect how much fuel operators pay in different provinces. Government policies also have a significant influence. Programs like the Clean Fuel Regulations (CFR) provide compliance credits to lower-carbon fuels, helping to offset the cost of renewable diesel and biodiesel for suppliers. Provincial and federal incentives, such as grants, tax credits, and subsidies, further reduce production costs, with these savings often passed on to fleet operators.

Market supply and demand also affect pricing. For example, during periods of oversupply, biofuel prices can drop significantly, while limited supply can drive prices up. The **Economic Insight Tool** developed to complement this report uses historical market trends to set default prices for biodiesel and renewable diesel across provinces. As of June 2024, with the market oversupplied for renewable diesel and various compliance incentives in place, biofuels are reaching price parity with diesel in many regions. This allows fleet operators to access biodiesel and renewable diesel at prices similar to those of conventional diesel, making these fuels a cost-effective option. Users of the tool can override these default values with prices provided by their fuel provider.

32 | HTEC, Accessed September 2024. https://www.htec.ca/faqs/#:~:text=How%20much%20does%20hydrogen%20cost,a%20price%20per%20kilometre%20basis

5.2 Incentives

Federal and provincial governments offer financial incentives to offset additional costs and support early adoption of ZEMHDVs. Key funding programs are summarized in Appendix B. Federal incentive programs include the Zero Emission Transit Fund (ZETF), which supports planning and deployment costs for public transit and school buses, and the Transport Canada Incentives for Medium- and Heavy-duty Zero-Emission Vehicles (iMHZEV) Program for other MHDV applications. While the ZETF allows for large-scale deployments, the iMHZEV program caps at 5 vehicles annually. Provincial programs also have caps, often limiting deployment to 10 vehicles per year depending on the application. Leveraging these stackable incentives can make projects highly cost-effective for fleet operators.

5.3 Economic Insight Tool

5.3.1 Powertrain and Market Applications

The **Economic Insight Tool** enables users to select their market segment and assess the economic implications of deploying alternative fuel technologies using a one-to-one replacement strategy. It includes twenty different MHDV applications, categorized based on specific market segments as presented below. The tool covers diesel, biodiesel (B20), renewable diesel (R99), and battery electric technologies for all applications. Gasoline, hybrid, and hydrogen fuel cell powertrains are only available for selected market applications, depending on data and market availability.

I - Passenger Transport:

- **School Bus:** Designed for transporting children to and from school and school-related activities (Type A, C, D).
- **Public Transit:** Includes vehicles used in municipal bus services (40 ft Class 8).
- **Passenger Van:** Smaller than buses, used for transporting smaller groups (Class 4).
- **Shuttle Bus:** Used for short trips such as airport shuttles or hotel transport (Class 4).
- **Coach Bus:** Used for longer-distance travel, often equipped with storage and comfortable seating (Class 8).

II - Freight and Cargo Handling:

- **Cargo Van:** Designed for transporting goods in urban settings (Class 2b-4).
- **Chassis Cab:** Base vehicles that can be fitted with various cargo bodies or equipment (Class 2b-4-6).
- **Box Truck:** Enclosed truck for transporting goods, often used by moving companies and couriers (Class 4-6-7).
- **Step Van:** Typically used for delivery services where frequent entry and exit is necessary (Class 3-6).
- **Tractor:** The driving unit of a semi-trailer truck.

III - Specialized Services:

- **Refuse:** Garbage trucks designed for waste collection (Class 8).
- **Fire Truck:** Equipped with firefighting apparatus and often emergency medical equipment (Class 8).

5.3.2 How to Use the Tool

Users should begin by navigating through the sections of the tool, starting with specifying their market of operations by selecting their province or territory, vehicle application, configuration, and weight class. Next, users can assess different powertrain technologies by selecting both existing and alternative fuels and inputting specific vehicle details such as fuel efficiency and number of vehicles. The tool then prompts users to define operational conditions, including average daily distance, number of operation days per year, and vehicle lifetime. Default values are provided for all parameters, but users can override these to better reflect their specific circumstances.

In the financial assumptions section, users can input discount rates, fuel costs, vehicle purchase prices, maintenance costs, insurance rates, depreciation rates, and infrastructure costs. Additionally, users can input subsidies per vehicle and for charging infrastructure. Subsidies per vehicle should be estimated by combining the federal incentive per vehicle, which is capped at five vehicles per year, with any available provincial incentives. The tool allows users to input costs for both refueling and charging infrastructure, accommodating the diverse needs of various powertrain technologies across multiple applications. Whether you are deploying biodiesel, hydrogen fuel cell, or battery electric vehicles, the tool provides flexibility in estimating the infrastructure costs associated with your chosen alternative fuel technology.

For refueling infrastructure, users can input the total costs directly, including expenses for refueling stations and necessary site upgrades. For charging infrastructure, users have two options for inputting costs.

The first option allows users to directly input the total charging infrastructure cost, including the costs of stations, construction, and grid upgrades. This option is suitable for users who have hired an electrical engineering firm that has provided a quote for the charging infrastructure needed based on the number of vehicles and the drive cycles of their deployment. The second option provides a more detailed, bottom-up approach, where users can select specific charging models with different power levels (i.e., charging speeds) and input the number of chargers needed along with their individual costs. Additionally, users can input the costs for infrastructure construction and grid upgrades separately. This method is ideal for users who have developed an understanding of the battery size and required charging power level associated with the vehicles they intend to purchase. Both options also allow users to input the total amount of federal and provincial subsidies available for charging infrastructure, ensuring an accurate and comprehensive assessment of the net costs.

Once all inputs are completed, the tool calculates and visualizes cumulative costs and net present value costs over the vehicle's lifetime. The tool also estimates operational GHG, NOx, and PM2.5 emissions for both existing and alternative fuel technologies, providing insights into potential emission reductions. By analyzing these results, users can make informed decisions about transitioning to sustainable vehicle technologies.

Why One to One Replacement?

The deployment of alternative fuel technology at scale often does not result in a one-to-one replacement of vehicles for many MHDV applications, as existing technology capabilities cannot always cater to all duty cycle applications, particularly for battery electric vehicles. Users should not expect to transition their entire fleet based on this tool alone. This tool is primarily intended for smaller pilot vehicle deployments to start assessing different technologies while taking advantage of existing financial incentives. After identifying the lowest payload and shortest routes in a fleet that can be reliably served by alternative fuels, users can use the tool to compare costs and take advantage of financial incentives designed to promote small-scale deployments. The default daily and yearly distances traveled for each vehicle configuration are based on existing models. However, for higher values, users should check model availability with their OEM, as there may be trade-offs between range and payload. Additionally, larger-scale deployments require an assessment of routes to design infrastructure at a system level, often resulting in fewer chargers than vehicles.

LEARN MORE

Tools

- **CTA's Economic Insight Tool**
  The accompanying **calculator** tool to this Guide enables fleets to assess the cost and emission reduction potential for the deployment of low- and zero-emission technology options.

- **PluginBC Fleet Procurement Analysis Tool**
  A total cost of ownership tool for more general use-cases. It offers the capability to assess different ownership models, types of vehicles, and purchasing scenarios.

- **Portland General Electric (PGE) Total Cost of Ownership Tool**
  A fleet total cost of ownership tool from Oregon-based PGE.

Additional Resources

- **BDC (2023), Workplace Charging in Canada**
  A list of EV charging incentive programs, equipment manufacturers and electric contractor associations across Canada.

- **BDC Electrify your Vehicle Fleet**
  A high-level overview for fleet owners considering electrification plus links to incentives and other funding options.

- **Transport Canada (2024) Incentives for Zero-Emission Vehicles (iZEV) Program Overview**
  The Incentives for Zero-Emission Vehicles (iZEV) Program, run by the Government of Canada, aims to make zero-emission vehicles more affordable by offering point-of-sale incentives for eligible electric, hydrogen fuel cell, and plug-in hybrid vehicles.

- **Canada Revenue Agency (2024) Capital Cost Allowances (CCA)**
  An explanation of the categorization and depreciation rates for different types of depreciable properties. This includes specific details and new classes for zero-emission vehicles, along with guidelines on how to claim CCA for each type on tax returns.

- **Road to Zero: Research and Industry Perspectives on Zero-Emission Commercial Vehicles**
  A comprehensive overview from research (National Renewable Energy Laboratory) and industry (Volvo Group North America) on ZEMDHVs.

- **EquiCharge: Electric Vehicle Incentives**
  A comprehensive list of EV incentives in Canada and other information for fleet owners to navigate the applications and planning services.

6. Target Setting

Fleet targets may be designed to contribute to larger organizational targets, such as net zero by 2050, associated interim targets (typically 2030) and others. They may also be designed to meet stakeholder/customer demands for lower emissions transportation, to get ahead of regulatory requirements, or to “future-proof” operations.

These targets need to be realistic, accounting for technology availability with the context of the fleet composition and operational requirements of the vehicles, and for capital and operational cost profiles.

6.1 Targets For ZEV Adoption

Setting fleet decarbonization targets is a tailored process, unique to each organization's specific business requirements and operational landscape. When considering adoption of ZEVs into the fleet, it's critical to acknowledge that ZEVs may not directly replace incumbent diesel engine trucks on a one-to-one basis due to factors such as vehicle efficiency, operational demands, and charging or refueling infrastructure availability. Moreover, the infrastructure required for charging or refueling does not need to match the number of vehicles on a one-to-one scale. This transition signifies a shift in service delivery methods, underlining the importance of change management in adapting to new operational models.

Piloting plays an indispensable role in understanding how ZEVs fit within specific business contexts and ecosystems. Initial pilot programs are recommended for gauging vehicle performance, infrastructure needs, and operational adjustments required for ZEV integration. Post-piloting, the gradual introduction of new vehicles allows for the refinement of ZEV targets based on real-world insights, ensuring a tailored and efficient fleet composition.

While there are currently more options available for medium-duty vehicles, the landscape for heavy-duty vehicles is rapidly evolving, with new alternatives emerging annually.

6.2 Targets For Low-Emissions Options

From an economic perspective, heavier vehicle weight segments have a higher breakeven point relative to their lighter weight counterparts, primarily due to their significantly higher incremental capital cost. Furthermore, there are simply fewer available ZEHDV options, with heavy duty vehicles lagging several years behind medium duty vehicles. The relatively large and increasing number of ZEMDV model options, along with their predominant use of less costly depot infrastructure, yield a high decarbonization potential in the short term and represent a more immediate and feasible decarbonization option.[33]

That is not to say that heavier classes are without emission reduction options. Despite full zero emission options being largely at the pilot stage in 2024, intermediate emission reduction options such as incorporating renewable alternative fuels or acquiring hybrid electric models can help fleet owners achieve their targets for lower emission operations in the short term, while more options become commercially available in the coming years.

6.3 Develop A Fleet Decarbonization Plan

Planning for fleet decarbonization should be approached in a manner consistent with other strategic planning within your organization.

33 | Delphi (2023) ‘ZEMHDV Market Readiness in Canada’

The initial goals are the ones that you will be focusing on first. Planning for these should be in-depth, identifying key success factors and potential risks to be assessed via pilot testing. Roles and responsibilities should be assigned.

These initial goals will represent the foundation for longer-term goals and overall targets, so the big-picture should inform development of this shorter-term planning.

6.4 Design Pilot Projects

High Level

Before committing to one technology type, pilot testing can reveal the benefits and use cases in the context of your organization's fleet operations, allowing for data collection on vehicle performance, maintenance needs, and operational challenges.

Tell Me More

Designing a pilot program involves selecting specific metrics to monitor. These metrics are critical as they can vary significantly based on local conditions such as climate, road quality, and operational conditions. The primary goal of the pilot is to provide a deeper, more nuanced understanding of the technology's performance. This goes beyond the general averages and worst-case scenarios typically provided by the OEMs. By closely analyzing how the technology operates in real-world conditions, you can identify potential areas for optimization and cost savings. This comprehensive data collection will be instrumental in understanding the full spectrum of operational dynamics and help in making informed decisions about scaling the technology.

The insights gained from the pilot will enable you to plan the expansion of the technology in a way that is both economically viable and optimized for your specific operational context.

Partnerships and Collaboration: To ensure success, both pilot testing and subsequent full deployment of new technologies necessitates collaboration among various stakeholders. Utilities are key partners for fleets considering deploying electric vehicles, as their policies regarding physical infrastructure build-out and electricity rate design will be vital to the success of vehicle charging.[34] Hydrogen suppliers are key partners for FCEV deployment. Depending on the chosen technology, infrastructure providers and new fuelling suppliers should be consulted to understand costs and maintenance requirements.

Fleet managers will likely need to partner with facility managers, who already interact with the local utility that provides power to the depot, distribution centre, or warehouse. Each fleet should have an account manager at their local utility, who can help connect them with appropriate programs and funding sources for electric truck charging infrastructure.[35]

Additional stakeholders to include are vehicle manufacturers or OEMs, who can help fleet owners understand all technical requirements for implementation and on-going maintenance. Also, consider involving consultants who can assist in designing the metrics for and processing the data from your pilot results.

34 | North American Council for Freight Efficiency (NACFE) (2020) 'A Trucking Fleet Primer For Commercial Truck Electrification' Available at: https://nacfe.org/wp-content/uploads/2020/07/Fleet-Primer-090522.pdf (Accessed: 14 April 2024)

35 | North American Council for Freight Efficiency (NACFE) (2020) 'A Trucking Fleet Primer For Commercial Truck Electrification' Available at: https://nacfe.org/wp-content/uploads/2020/07/Fleet-Primer-090522.pdf (Accessed: 14 April 2024)

Identify Learning Objectives and Collect Data: By clearly identifying learning objectives early on, organizations can understand what key aspects they need to understand to be able to scale and replicate the chosen technology into their wider operations. These could include factors such as the impact of weather conditions on vehicle performance, driving behaviour changes, maintenance schedule changes, and duty cycle changes. By setting these in advance, the necessary data can be collected to be analyzed and understood to build a body of knowledge to better prepare for future implementations and adoption.

Understanding the Costs and Secure all Available Supports for Piloting: The costs associated with ZEV adoption can represent a significant financial investment, especially when comparing the upfront costs to those of traditional ICE vehicles. Piloting can help organizations understand what technology is right for their operations in a financially responsible fashion. Therefore, being aware of what programs and tax credits are available from all government levels can help ease the financial burden a comprehensive understanding and commitment across the organization.

LEARN MORE

Additional Resources

- **Road to Zero: Research and Industry Perspectives on Zero-Emission Commercial Vehicles**
  A comprehensive overview from research (National Renewable Energy Laboratory) and industry (Volvo Group North America) on ZEMDHVs.

- **Electric Autonomy EV Fleets Pro Course**
  This course is designed for fleet owners, operators, and sustainability stakeholders interested in integrating light- and medium-duty electric vehicles into their business operations, providing essential insights into the benefits of EVs for both business efficiency and environmental impact.

- **BDC Electrify Your Vehicle Fleet**
  A high level overview for fleet owners considering electrification plus links to incentives and other funding options.

CASE STUDY

Purolator Fleet Electrification

Purolator has set a science-based net-zero by 2050 goal, supported by an interim 2030 goal to reduce Scope 1 and 2 GHG emissions by 42 percent. The company plan to achieve this includes electrifying 60 per cent of its last-mile delivery vehicles and investing in clean-fuels and other low-carbon technologies.

Purolator has long been an early adopter of low-carbon technologies, demonstrated by the introduction of more than 500 hybrid-electric vehicles into its fleet in 2005. From 2020 to 2022, it implemented a series of pilot projects to test all-electric vehicles, from electric cargo bikes (e-bikes) and compact low-speed vehicles to fully electric delivery vans. In 2023, Purolator announced a $1-billion, seven-year Canadian network electrification plan that includes the purchase of 3,500 fully electric delivery trucks.

Driving Change at Purolator

Purolator is committed to reducing its environmental footprint by tackling its fleet emissions. Beyond reducing its own emissions, Purolator seeks to support innovation more widely, including through partnerships with post-secondary institutions and other industry leaders to advance clean technology. Purolator operates in urban environments, so this has led to trialing novel vehicle types such as the e-bikes and compact vehicles. The company remains keen to work with innovators to test other unique solutions.

Plan, Test, Repeat

Prior to the 2020 pilots, Purolator's sustainability and fleet teams worked together to create an initial roadmap – with consideration given to vehicle types, routes and locations of terminals to better understand which routes can be electrified and at what times. Pilots were designed to test technology options, to troubleshoot issues that arose – both at the outset and over time – and to identify conditions for success.

When ready to deploy at scale, Purolator rolls out new vehicle technology on a terminal-by-terminal basis. This allows for lessons learned to be applied to the next deployment.

The overall roadmap continues to evolve based on learnings from the pilot testing, deployments, resources and commercial readiness of new technologies.

Low Emissions on the Road to No Emissions

To attain emissions reductions in the fleet segments, routes and locations that are not yet suitable for electrification, Purolator is turning to clean fuels. In Quebec and British Columbia, fuel regulations and pricing support the use of hydrogenation-derived renewable diesel (HDRD) in blends from R20 (QC) to R100 (BC). Purolator plans to use this to fuel the heaviest and most challenging portion of its fleet to decarbonize– the Class 8 tractor-trailers. In other locations, where costs of HDRD remain prohibitive, or where sourcing sufficient supply is challenging, biodiesel provides an alternative.

CASE STUDY

It can be used seasonally in higher blends to help reduce emissions, at a cost similar to that of petroleum diesel.

Wins

When Purolator began deploying zero-emissions vehicles, they were initially concerned about how drivers might react to the change – they didn't need to be! Chris Henry, Purolator's Director of National Fleet reports that one of the benefits of going electric is modernizing the fleet. Drivers appreciate the vehicles' modern design features and comfort, and they like the fact that these vehicles produce less noise and emissions.

There is a real sense of pride in greening the fleet. People are proud to work for a company that is being proactive in reducing emissions and demonstrating environmental leadership. That feeling extends to existing and potential new customers through increased brand awareness and community engagement when people see the e-bikes or electric trucks out on the road.

Reduced maintenance requirements have been another big win, says Purolator Fleet Engineer Nim Takhtar. The heavier vehicles can lead to increased brake and tire wear, and the company is seeking out slower-wearing options to help manage that. But on the whole, maintenance needs and related costs have gone down for the electric delivery trucks.

Lessons Learned

That's not to say that there have been no bumps in the road. Power supply for vehicle charging was an early hurdle as many of the terminals initially could not supply the power required to charge the fleet in-house. The company had to work with partners to supply the power they needed. Based on their experience, they recommend engaging utilities as early as possible. Smaller utilities in particular may not be ready for commercial electric vehicle implementation and may struggle. Vehicle acquisition continues to be a challenge, with some vehicles arriving earlier than anticipated and some much later.

Change management has been one of the most critical components of the success of the project to date. Purolator has a staff member dedicated to informing, engaging and educating all parties on the who, what, how, why and where of the decarbonization roadmap and its various milestones.

Among the biggest challenges has been how to tell the story: is the transition really happening? Should we wait until the vehicles and the power to charge them are more available? Cindy Bailey, Purolator's Corporate Sustainability Officer says that decarbonizing is important, and the best time to start is now.

> *We are committed to taking meaningful action towards a more sustainable future. At Purolator, we believe that sustainability isn't just a goal, it's our responsibility. We have set ambitious goals for ourselves, and we are working very hard every day to reduce our carbon footprint and protect our environment. We are committed to investing in alternative fuel vehicles and innovative low-carbon solutions to help us achieve our interim goals and net-zero-emissions by 2050.*[36][37]

36 | https://www.purolator.com/en/articles/delivering-our-planet-conserving-energy-and-reducing-waste

37 | https://www.purolator.com/en/about-purolator/our-commitment-environmental-sustainability

7. Identify Energy Supply

7.1 For BEVs, Connect With Utility

High Level

Before installing EV charging stations, it is crucial to communicate with your local distribution company (LDC) or electrical utility. While implementing a small-scale BEV pilot might be feasible under the existing power capacity at your depot, large-scale electrification requires higher power loads. These are often not readily available at a depot and necessitate careful planning with your electricity provider or the addition of alternative solutions like stationary battery storage or a microgrid.

Tell Me More

Utility infrastructure consists of multiple components, including generation, transmission, and distribution. Each geographic area has an existing capacity determined by its location and infrastructure. Introducing charging infrastructure at a depot requires utilities to verify available capacity at the distribution level to accommodate the necessary loads. Depending on the scale of the deployment, the required upgrades may vary widely in terms of magnitude, cost and timeline. These can range from transformer upgrades (taking from six months to two years) to the upgrade or replacement of distribution substations for substantial loads, which can take up to six years.

Utilities typically perform demand projection studies every five years and construct distribution capacity based on the anticipated electrical loads in each geographic region.

These upgrade costs are then reflected in tariffs. As of 2024, grid upgrades for MHDV electrification are not typically included in utilities' demand projections, as this demand is not yet confirmed, and utilities require approval to proactively build infrastructure. Consequently, the costs associated with grid upgrades often fall on the fleet. However, for certain applications federal or provincial incentive programs may cover a portion of these costs. It is therefore imperative to approach your local utility at the earliest opportunity and share any electrification plans well in advance. This early communication allows them to potentially consider your future load needs in their planning and projections and advise you on available financial incentives for your deployment.

Typical steps include:

Initial Contact: Reach out to your local distribution company (LDC) or utility provider early in the planning process. Discuss your plans to integrate EVs into your fleet and the potential increase in electricity demand.

Understanding Rates and Programs: Inquire about special rates, programs, or incentives available for EV charging. Understand the different billing structures and how they may impact your operating costs.

Grid Capacity and Upgrade Requirements: Determine if the existing electrical grid can support your charging needs or if upgrades are necessary. Discuss any potential costs and timelines for such upgrades.

Technical Assistance: Request technical assistance from your LDC/utility or consultant in planning the charging infrastructure. They can provide valuable insights into managing load and optimizing energy use.

Ongoing Communication: Establish a point of contact and maintain open lines of communication with your utility. They can provide ongoing support and information about new programs or incentives.

7.2 For FCEVs, Identify Fuel Producer/ Provider

High Level

In Canada, hydrogen refueling infrastructure is still in its early stages. One of the challenges of hydrogen is its transportation over long distances. Without dedicated infrastructure, i.e., hydrogen-specific pipelines, transporting hydrogen via trucks is the primary means of receiving hydrogen fuel. Therefore, to keep fuel delivery costs down, the required amount of hydrogen fuel should be satisfied either by a nearby hydrogen production hub or, if possible, by on-site low-carbon or zero emission hydrogen production.

Connecting directly with a hydrogen producer or supplier will be crucial to securing a steady supply of sustainably produced hydrogen. The Canadian Hydrogen Association has developed a map of hydrogen producers across Canada, containing status details, production technology, and production capacity (see below under Tools). Establishing an early relationship with a producer within your area will help you to understand whether the capacity can be met. This should be done before the purchase of any hydrogen vehicle, as the network of public hydrogen refueling stations is extremely limited.

For perspective on their limited availability, at the time of writing, there were only five publicly available hydrogen refueling stations across the country: four in British Columbia and one in Quebec. An additional refueling station was under development at Toronto's Person International Airport.[38]

Therefore, identifying and collaborating with hydrogen providers who are actively involved in expanding Canada's hydrogen refueling network is essential. This collaboration can ensure access to reliable and efficient hydrogen refueling solutions tailored to the needs of MHDV fleets. Furthermore, the price of hydrogen is expected to decrease as the hydrogen economy expands across different regions, making it more viable for MHDVs.

Tell Me More

- **Initial Contact:** Start by reaching out to potential hydrogen producers to discuss their production capabilities and the types of hydrogen they offer (green, blue, grey). This initial engagement will help gauge their ability to meet your specific needs and compliance with environmental standards. For onsite production, initial contact should also involve consulting with companies that specialize in hydrogen production equipment to understand the technological and infrastructural requirements.

38 | CBC News (2023) 'Pearson airport to get hydrogen refueling station'. Available at: https://www.cbc.ca/news/canada/toronto/pearson-airport-hydrogen-refueling-station-1.6898701 (Accessed: 10 December 2023).

- **Delivery and Logistics:** Evaluate the producer's logistics capabilities, including their methods for hydrogen delivery, frequency, reliability, and the geographic reach of their service. It is important to ensure that they can consistently meet your fleet's demand without delays. Consider the proximity of the hydrogen production site to your operations, as this will significantly impact delivery logistics and potential costs.

- **Onsite Production (for electrolysis on site):** As explored in **Section 4.5.2**, there are many options for producing hydrogen, and the exact pathway will depend on a variety of factors including local expertise, availability of renewable electricity and water or other possible feedstocks and pathways. Assessing the feasibility of installing an onsite hydrogen production unit to produce hydrogen directly at your facility should include a detailed analysis of space requirements, energy sources, initial capital investment, operational costs, safety and risk management.

- **Technical Assistance:** Whether you choose external delivery or onsite production, ensure that the hydrogen producer or equipment supplier offers comprehensive technical support. This support should cover installation, operation, and troubleshooting of the hydrogen infrastructure.

- **Ongoing Communication:** Maintain open lines of communication with your hydrogen supplier to manage and adapt the supply agreement as your fleet's needs evolve. Regular updates regarding hydrogen production advancements, changes in regulations, and new sustainability practices are essential for a long-term partnership. For onsite production, this also means regular consultations with your equipment provider to ensure that your system remains up-to-date and compliant with the latest safety and environmental standards.

7.3 Sourcing Alternative Fuels

High Level

Before incorporating alternative fuels into your fleet's operations, a good first step is to establish connections with a fuel supplier or producer. With the introduction of the Canadian Clean Fuel Regulations, producers are incentivized to reduce the carbon intensity of their offered fuels and having a reliable off-take partner will be mutually beneficial. The obligation to reduce the carbon intensity of fuels under the Federal Clean Fuel Regulations and some provincial regulations has provided a clear signal to producers of alternative fuels that there will be steady demand for their fuels. At the time of writing, two new HDRD facilities were operational in British Columbia and Newfoundland and Labrador, and five more were planned or under construction across British Columbia, Alberta and Quebec.[39]

Although it is assumed that the majority of refueling will occur at the depot, NRCan's electric charging and alternative fuelling stations locator (see below under Tools), shows only one publicly available refueling station (located in Victoria, BC) offering biodiesel in concentrations of B20 and greater. However, it is expected that as demand grows, off the rack blends of biodiesel and HDRD will become more widely available.

39 | Canada Energy Regulator (2023) 'Market Snapshot: New renewable diesel facilities will help reduce the carbon intensity of fuels in Canada'. Available at: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2023/market-snapshot-new-renewable-diesel-facilities-will-help-reduce-carbon-intensity-fuels-canada.html (Accessed: 5 March 2024).

Tell Me More

Biodiesel can be sourced in bulk directly from producers or suppliers, who often handle the blending process. However, if blending is done in-house, proper equipment and knowledge of biodiesel properties are necessary to ensure compliance with fuel standards and to maintain engine warranties.

The current production of HDRD in Canada is relatively low, primarily due to more lucrative federal and state-level incentives and policies in the United States, which has facilitated the build-out of the HDRD industry and also driven significant demand. Currently, more than half of the diesel used in California has been replaced by cleaner fuels, including HDRD.[40]

HDRD is typically available through major fuel suppliers and can be delivered in bulk. Since it is a drop-in fuel, existing diesel storage and dispensing systems at depots can usually be used without modifications. Establishing a purchasing agreement with a reliable supplier is crucial, considering the potentially higher costs associated with renewable diesel.

Both the availability and cost of biodiesel and HDRD are location specific. British Columbia currently stands out as the province offering the most favourable regulations and incentives for the adoption of these fuels. Here, supportive policies and programs make the integration of HDRD and biodiesel into fleet operations financially more feasible compared to other parts of Canada.

40 | https://ww2.arb.ca.gov/news/first-time-50-california-diesel-fuel-replaced-clean-fuels

For fleet owners looking to partner with local biodiesel and HDRD producers, the "Additional Resources" section below provides a list of suppliers across Canada. These lists serve as an excellent starting point for identifying and connecting with suitable fuel partners in your geographic area.

Some typical steps for sourcing alternative fuels include:

- **Initial Contact:** Reach out to potential alternative fuel suppliers or producers early in the planning process. Discuss your fleet's needs, potential volumes, and delivery schedule requirements.
- **Understanding Pricing and Contracts:** Inquire about bulk purchasing options, short-term contracts if the fuel is for piloting, long-term contracts if appropriate, and price stability measures.
- **Infrastructure and Delivery Logistics:** Determine if your existing storage facilities are suitable for alternative fuels or if upgrades are necessary. Discuss any potential costs and requirements for infrastructure changes, such as additional storage tanks or upgraded fuel handling systems.
- **Technical Assistance:** Request assistance from suppliers in understanding the specific handling, blending, and usage requirements of alternative fuels. They can provide valuable insights into maintaining fuel quality and optimizing performance.
- **Ongoing Communication:** Establish a point of contact with your fuel supplier and maintain open lines of communication. They can provide ongoing support, information about new developments in fuel technology, and adjustments to delivery schedules based on usage patterns, or any seasonal differences in fuel usage that should be accounted for.

LEARN MORE

Tools

- **Electric Charging and Alternative Fuelling Stations Locator**
  by Natural Resources Canada (NRCan) helps drivers and operators understand where it is possible to refuel or charge your vehicle across Canada and the US. Filters include searching for charging stations, hydrogen refueling, biodiesel (B20 and above), and HDRD (R20 and above).

- **Hydrogen Production Map**
  by the Canadian Hydrogen Association maps hydrogen production by production capacity and technology used. Canada-wide.

- **Advanced Biofuels Canada Members Map**
  A map of the Advanced Biofuels Canada (ABFC) showing the geographic distribution of their activities. Users can look up facility types, product types and other criteria to help locate potential partners near their facilities.

Additional Resources

- **Biodiesel Producers and Distributors**
  provided by Advanced Biofuels Canada (ABFC). Member organizations of ABFC that operate the production and distribution of biodiesel.

- **Renewable Diesel (HDRD) Producers and Distributors**
  provided by Advanced Biofuels Canada (ABFC). Member organizations of ABFC that operate the production and distribution of HDRD.

- **Renewable Industries Canada**
  is an industry association, working to promote the advancement of innovation in biofuels and other bio products.

- **Argus Media**
  is a leading independent provider of energy and commodity price benchmarks. Provides analysis and market coverage for international biofuel pricing and news. Member of ABFC. (Paid service).

- **OPIS Biofuels Daily Report**
  A daily breakdown of biofuel and HDRD pricing, market analysis, and real-time news. Member of ABFC. (Paid service).

- **RMI (2023), Preventing Electric Truck Gridlock**
  This report highlights the challenges facing rapid electrification of the trucking industry, along with solutions to ensure that grid power is available.

8.

Plan for Charging/ Refueling Infrastructure

8.1 BEV Charging

8.1.1 Conduct Facility Assessment

High Level

Charging requirements may necessitate changes to depots, yards and facilities. Conducting a comprehensive facility assessment is critical for understanding the specific needs of your fleet and facility prior to the installation of charging infrastructure. Evaluating the vehicles, layout, and available power capacity at your site is essential for developing a tailored electric vehicle deployment plan. Furthermore, understanding any local permitting or code requirements associated with the installation of new energy or fueling infrastructure must be understood. This may include evaluating building and electrical codes, permit requirements, and utility interconnections.

Tell Me More

A facility assessment is required to evaluate the electrical layout of your location and quantify the existing available power capacity at your depot. The charging infrastructure also requires physical space, and a site assessment helps to determine the number of charging stations that can be accommodated within your depot, along with ease of access, parking configurations, and safety considerations.

The assessment should cover installation considerations, including the potential need for trenching or upgrading electrical panels. Factors such as distance from the power source, obstacles between charging stations and the electrical panel, and the condition of existing electrical infrastructure should be evaluated.

This information is critical for developing a charging infrastructure plan that aligns with what can realistically be accommodated at the depot under its existing conditions and footprint.

Steps include:

- **Site Evaluation:** Assess the physical layout of your facility to identify potential locations for charging stations. Consider factors like proximity to the electrical supply, space for vehicles, and accessibility for drivers.
- **Electrical Capacity:** Evaluate the existing electrical capacity of your facility. Determine if additional transformers, panels, or meters are required to support the charging infrastructure.
- **Upgrade Needs:** Identify any necessary upgrades to the electrical system and any associated costs. This may include new circuits, conduit, wiring, or other electrical components.
- **Safety and Compliance:** Ensure that all infrastructure plans comply with local building codes, electrical codes, and safety standards. Consider the placement of charging stations to avoid obstructing traffic flow and ensuring driver safety.

8.1.2 Charging Infrastructure Planning Study

High Level

After engaging with your LDC/utility and completing a facility assessment, utilize the gathered data and an operational analysis of your fleet characteristics to determine the scope of your deployment. This will form the basis for developing a tailored charging infrastructure plan.

Tell Me More

Consider whether you want to own, operate and maintain charging infrastructure and plan these requirements accordingly or partner with others to do so.

Design your charging infrastructure based on route analysis, site assessment, and discussions with your local utility. Ensure the plan accommodates current requirements and allows for future expansion. Consider the types of chargers (Level 2, DC Fast Chargers), their placement, and the integration of smart charging solutions.

A careful analysis based on the duty cycle of each vehicle should be conducted to select the most appropriate chargers. Understanding specific usage patterns, such as the frequency and duration of trips and the subsequent downtime, is essential. Considering chargers with multiple ports or cords can further enhance operational efficiency. These multi-port chargers allow several vehicles to be charged simultaneously or consecutively from a single station, optimizing the use of space and electrical connections. This setup is especially beneficial when a detailed drive cycle analysis of the fleet reveals that multiple vehicles are available to charge at overlapping or complementary times, reducing the need for extensive installation work and minimizing the physical footprint of charging stations.

Incorporate charging schedule planning into your strategy. Unlike fuel costs for ICE vehicles, electricity prices can vary significantly throughout the day. Many regions employ Time-of-Use (TOU) pricing, leading to higher costs during peak demand periods and lower costs during off-peak times. Leveraging TOU pricing by scheduling charging during off-peak hours can lead to substantial savings and reduce grid strain. Additionally, account for demand charges, which are based on the peak power usage within a billing cycle. Staggering the charging of multiple vehicles or adding stationary battery storage to facilitate peak shaving can mitigate high demand charges and optimize operational costs.

Construction and operating permitting requirements must also be factored in during the planning stage. These permits, which vary by jurisdiction, ensure that the installation complies with local building codes, electrical standards, and zoning regulations. Obtaining these permits can take time and may involve coordination with multiple agencies, so early engagement is critical to avoid delays.

Consider consulting with a firm specializing in electric fleet infrastructure to navigate complexities like TOU pricing and demand charges effectively. These firms can provide valuable insights and proprietary tools for detailed planning.

Finally, establish a realistic timeline for the installation process, factoring in planning, permitting, equipment delivery, and commissioning of charging stations. Anticipate potential delays to ensure the timeline is practical and achievable. Planning for these aspects in advance will streamline the transition to electric vehicles and help avoid unforeseen challenges.

Steps include:

- **Charging Needs Analysis:** Based on your fleet composition and usage patterns, determine the types and quantities of charging stations required. Consider the mix of Level 2 and DC Fast Charging stations based on vehicle needs and dwell times.

- **Scalability:** Design your infrastructure to be scalable, allowing for easy expansion as your fleet grows or as technology advances.

- **Cost Estimation and Budgeting:** Estimate the total costs, including equipment, installation, maintenance, and electricity. Include permitting costs and explore financing options or incentives.

- **Vendor Selection and Procurement:** Research and select vendors for charging equipment and installation services and qualified maintenance. Consider factors like reliability, cost, warranty, and customer service.

- **Installation and Commissioning:** Work with contractors and your utility to install and commission the charging stations. Ensure all required construction and operating permits are obtained and that all work is performed to code and that charging stations are properly tested before being put into service.

- **Maintenance and Operations:** Develop a plan for ongoing maintenance and operations. Include regular inspections, cleaning, and repair of charging stations to ensure reliability and longevity. Consider redundancy and preventative maintenance for critical vehicle operation (i.e., emergency response).

8.2 FCEV Refueling

8.2.1 Conduct a Facility Assessment

FCEV

Supplied Hydrogen (either liquid or gaseous)

- **Site Evaluation:** Evaluate the facility to identify suitable areas for hydrogen storage tanks. Key considerations should include proximity to delivery access points and secure, ventilated areas dedicated to hydrogen storage to minimize safety risks. Understand any design, construction and operating permitting or regulatory requirements.

- **Infrastructure Requirements:** Depending on technology selection, the installment of either a high-pressure storage tank designed to handle gaseous hydrogen, or cryogenic tank for containing liquid hydrogen. Liquid hydrogen requires cryogenic storage tanks that can maintain temperatures around -253°C, while tanks storing gaseous hydrogen should be compatible with 700 bar pressure. Ensure that the facility has appropriate offloading areas and equipment for safely transferring hydrogen from delivery modules to storage units.

- **Safety and Compliance:** Implement rigorous safety protocols for handling and storing hydrogen, including leak detection systems, proper ventilation, and emergency shut-off mechanisms.

Onsite Hydrogen Production

- **Site Evaluation:** Understand that several options exist, including electrolysis, onsite steam reformation, and pyrolysis. Identify potential locations for hydrogen production. Consider factors such as access to water and electricity supply (for electrolysis), integration with onsite renewable energy and space for the necessary equipment.

- **Safety and Compliance:** Similar to delivered hydrogen, onsite production must adhere to stringent safety standards. This includes the installation of sensors and alarms for detecting hydrogen leaks, fire suppression systems, and controlled access to production areas. In addition to hydrogen storage and handling, the chosen production equipment may have specific safety compliance and training requirements that should be well understood.

8.2.2 Hydrogen Refueling Infrastructure Planning Study

High Level

Developing a hydrogen refueling infrastructure plan is a critical step that follows a thorough assessment of your current facilities. This strategic plan should detail the necessary measures to secure sufficient access to hydrogen refueling options for your fleet.

There are two standard pressures for hydrogen refueling: 350 bar and 700 bar. These pressures cater to different vehicle needs, with 350 bar typically used for buses and lift trucks like forklifts, and 700 bar for passenger vehicles and other lighter-duty applications. However, several of the new heavy-duty FEV trucks under development will also fill at 700 bar to allow for longer ranges without increasing tank capacity.

Tell Me More

Steps include:

- **Refueling Needs Analysis:** Based on the operational analysis of your fleet, including vehicle types and usage patterns, determine the necessary capacity and type of refueling required.

- **Permitting:** Assess permitting and code requirements impacting design, construction and operation

- **Design:** Design the refueling infrastructure to be scalable, allowing for adjustments and expansions as your fleet grows or as hydrogen technology evolves. This could involve modular refueling components that can be upgraded or expanded without significant disruptions.

- **Cost Estimation and Budgeting:** Estimate the total costs involved in establishing the hydrogen refueling infrastructure, including equipment, installation, and ongoing operational costs. Factor in potential costs for safety systems and compliance with regulatory standards. Explore financing options, government incentives, or grants available for hydrogen infrastructure projects to manage upfront costs and long-term investments effectively.

- **Vendor Selection and Procurement:** Conduct thorough research to select vendors with expertise in hydrogen refueling systems. Consider their reliability, experience in the hydrogen industry, safety record, and customer service. Evaluate multiple vendors to ensure competitive pricing and technology offerings. Engage with vendors that can provide comprehensive services from design to installation and after-sales support.

- **Installation and Commissioning:** Work closely with chosen vendors and contractors to oversee the installation process, ensuring that all components meet industry standards for safety and efficiency. Conduct a detailed commissioning process to ensure the refueling infrastructure operates as designed. This should include safety checks, pressure tests, and training for personnel on operating the refueling equipment.

- **Maintenance and Operations:** Develop a maintenance plan to ensure the long-term reliability and safety of the refueling infrastructure. This should include regular inspections, leak tests, and updates to safety protocols. Train staff thoroughly in the operations and emergency procedures associated with hydrogen refueling to ensure safe and efficient handling of the fuel.

8.3 Alternative Fuels

As there is significant overlap in fueling infrastructure requirements between petroleum diesel and alternative fuels, there is less requirement for new refueling infrastructure.

- **Site Evaluation:** Assess the layout for potential modifications in storage areas to accommodate fuel storage tanks. Biodiesel may degrade some materials, requiring specific types of tanks and handling systems. Consider proximity to existing diesel infrastructure and space needed for blending units if onsite blending is planned. HDRD often requires fewer changes as it is chemically similar to conventional diesel and less corrosive.

- **Storage Considerations:** Evaluate the compatibility of existing storage tanks and fueling infrastructure with biodiesel, which can degrade certain materials in higher blends. Biodiesel is sensitive to temperature and contamination, necessitating potentially heated and insulated tanks to prevent gelling in cold temperatures and possible mold growth contamination. It is recommended that fuels are stored in cool, dry conditions to mitigate possible microbial contaminations. Upgrading to biodiesel-compatible materials like stainless steel or coated steel is recommended. Filtration should be done to remove any organic sediments for fuel that has been stored for several month. Good storage practice is to not store biodiesel blends for more than six months.

HDRD typically does not require specialized storage solutions beyond those used for petroleum diesel, but it's essential to consult with either your HDRD fuel supplier or a knowledgeable expert of any nuanced differences.

LEARN MORE

Tools

- **Electric Charging and Alternative Fuelling Stations Locator**
  by Natural Resources Canada (NRCan) helps drivers and operators understand where it is possible to refuel or charge your vehicle across Canada and the US. Filters include searching for charging stations, hydrogen refueling, biodiesel (B20 and above), and HDRD (R20 and above).

- **Hydrogen Production Map**
  by The Canadian Hydrogen and Fuel Cell Association details all the hydrogen fuel producers across Canada.

Additional Resources

- **Hydrogen For Heavy-Duty Long Haul**
  A webinar hosted by the Edmonton Region Hydrogen HUB and moderated by Emissions Reduction Alberta. Presenters from the North American Council for Freight Efficiency (NACFE) focus on using hydrogen-based power trains for heavy-duty Class 8 long-haul freight routes pulling van trailers.

- **NACFE (2023), Charging Forward with Electric Trucks**
  This report comprehensively covers the considerations for deploying charging infrastructure at a depot. It includes understanding electricity basics and utility operations to estimate charging costs, facilitate charger installation, and maximize fuel savings from electric vehicle usage.

- **Canadian General Standards Board (2020) Diesel Fuel Containing Biodiesel (B6-B20**
  This report contains information regarding the safe handling and storage of biodiesel blends.

- **CIB Charging and Hydrogen Refueling Infrastructure Initiative**
  Information from the Canada Infrastructure Bank (CIB) on getting financing support to partner and develop hydrogen refueling infrastructure.

9. Vehicle and Charging/ Refueling Infrastructure Procurement

9.1 Vehicle And Charging/Refueling Infrastructure Procurement

When transitioning to alternative fuel technologies such as biodiesel, renewable diesel, electric, and hydrogen fuel cell, OEMs can play a role in specifying vehicle options and capabilities.

For biodiesel and renewable diesel, OEMs should be consulted to ensure that vehicle engines are compatible with these fuels and what blending rates will be covered under existing warranties. They can also provide information regarding any necessary modifications or maintenance considerations. The Canadian General Standards Board Catalogue (CGSB) provides additional information guidelines for biodiesel at low blends (B1-B5),[41] medium blends (B6 – B20)[42] and B100.[43]

In the case of BEVs and FCEVs, OEMs can provide vital information about vehicle payload capacities and range. Further, they can advise on their capacity to provide comprehensive maintenance support in the region where fleet vehicles will be located. Access to reliable, effective maintenance services are essential for the successful operation of new and complex technologies.

OEMs may also advise on charging or refueling infrastructure solutions, including confirming compatibility with specific brands and ensuring proper software integration for efficient operation.

41 | https://publications.gc.ca/site/eng/9.884945/publication.html

42 | https://publications.gc.ca/site/eng/9.884952/publication.html

43 | https://publications.gc.ca/site/eng/9.915799/publication.html

By gaining a clear understanding of these aspects through discussions with OEMs and relevant local energy providers, fleet operators can make informed decisions about vehicle and infrastructure investments. This approach ensures that their selections are not only compatible but also well-supported, optimizing performance and cost-efficiency and facilitating a smoother transition to alternative fuels.

9.2 Turnkey Solutions For Fleet Operations

For fleet operators interested in a comprehensive, hands-off approach to adopting low- or zero-emission technologies, a turnkey solution is recommended. Turnkey solutions involve a single provider who handles all aspects or a portion of procurement and operations of vehicles and their respective infrastructure. This approach is especially beneficial for fleets transitioning to emerging technologies like electric and hydrogen fuel cell vehicles.

The service provider takes responsibility for the entirety or a portion of the process, from acquiring the appropriate vehicles and setting up the necessary charging or refueling infrastructure to managing the ongoing operations of these systems. The billing for these services is typically based on a subscription model, which simplifies budgeting and financial planning for fleet operators. This model not only reduces the administrative burden on the fleet operator but also ensures that the fleet has access to the latest technologies and maintenance practices, all while maintaining predictable operating costs.

By opting for a turnkey solution, fleet operators can leverage the expertise of specialists to streamline their transition to alternative fuels, ensuring that both the technological and operational transitions are smooth and cost-effective.

CASE STUDY

Milton Transit Bus Repower

MTB Transit Solutions Inc., through its ZEV Clean Power initiative, is partnering with the Town of Milton to pilot the conversion of a mid-life diesel bus to electric battery power. The ZEV Clean Power initiative was funded with support from national research funds, as well as research and development support from Canadian post-secondary institutions. This type of retrofit project has the potential to both extend the life of existing diesel vehicles, while supporting transit companies and other medium and heavy-duty vehicle fleets in meeting emissions reductions targets on time and on budget.

Repowering Diesel Transit Buses

Due to their high-duty cycles, transit buses are typically refurbished at midlife (after 6 to 8 years of operation) via a complete overhaul to address any hidden structural integrity issues due to corrosion and wear and tear. This extends the useful life of the bus at a fraction of the cost of buying new. It also provides an ideal opportunity to convert to zero-emission propulsion. To accomplish this, MTB removes the diesel components, including the ICE engine, transmission, steering, HVAC, air compressor, radiator system and fuel tank. It then installs new battery electric components, including an electric motor, EHVAC, electric steering, electric air compressor, auxiliary coolant heater and battery packs with associated cooling.

MTB works with Forsee Power, who is providing the Zen 16 Slim battery system. This ultra-thin battery pack requires limited space thanks to its high energy density, and its reduced weight is also strategic. MTB maintains the bus's Gross Vehicle Weight (GVW) to ensure that there are no impacts to passenger capacity or handling of the vehicle. This also limits the additional wear and tear on components such as brakes and tires that often come with electrification.

Why Repower?

Repowering costs about half as much as purchasing a new electric bus, and takes about 6 to 9 months to complete, as compared to the current 18- to 24-month wait time for a new model. A repowered bus looks, feels and drives like a brand-new electric bus, and comes with benefits such as reduced noise and vibration.

CASE STUDY

Further, MTB reports that "operating a clean propulsion system, like ZEV Clean Power, is 41 percent cheaper than diesel power and extends the life span of the bus by 50 percent."[44]

Repowering is not just for buses! MTB offers a diesel to battery electric conversion program for shuttle, courier, and class 6-8 trucks that provides the same benefits that are realized on the transit conversion. Further, they have also developed a diesel to hydrogen conversion program for transit and class 7-8 truck fleets.

Driving Change in Milton

Since declaring a climate emergency in 2019, the Town of Milton applies a sustainability and climate lens to all of its plans and projects, including its fleet strategy.
The Town is undertaking a Transit Battery Electric Bus Feasibility Study and Transition Plan, which will provide a road map for the implementation of electric buses and charging infrastructure.

Milton will be the first municipality in Canada to pilot mid-life, diesel-to-battery electric conversion technology on a transit bus. The project budget of $882,000 includes the costs of repowering the existing 2017 Nova Bus, one year of maintenance, and all required training (including for the Town's emergency responders). It also includes installation of a 150 kW charger from ABB – a modular system that will allow Milton to scale up charging capacity as required. MTB worked closely with the local utility to coordinate power supply for the charging infrastructure.

44 | Innovating Municipal Transit through Refurbished and Repowered Fleets, Gara Hay, MTB Transit Solutions Inc.

Pilot Design

During the pilot phase, which will last for about a year to ensure testing in all sorts of weather conditions, the bus will shadow in-use buses on their routes. Weights on-board will replicate passengers. Milton will be seeking to understand how passenger load profiles, elevation, climate, and travel patterns affect the battery range and bus performance, and how schedules can be optimized to maintain service reliability.

As this will be Milton's first electric vehicle, the pilot will allow the Town of Milton not just to test the vehicle itself, but also to learn more about charging technologies, software systems and service planning approaches before committing to a broader implementation.

> *We've been working with transit authorities and truck fleets across Canada for 45+ years to keep their vehicles running smoothly. With our ZEV Clean Power initiative, we are taking that to the next level by extending the life of these vehicles through the repowering process. Repowering from diesel to battery electric or hydrogen fuel cell is a cost-effective and eco-friendly approach that breathes new life into aging fleets. By integrating these innovative technologies, we can enhance the performance, efficiency, and environmental impact of the vehicles, creating a win-win situation for both the fleets and the communities in which they operate.*
>
> *In the face of growing environmental concerns and the need to reduce emissions, finding sustainable alternatives for heavy duty fleets is becoming more crucial than ever, and repowering is a great way to help fleet operators to achieve GHG reduction goals sooner, reduce harmful air contaminant emissions and save money thanks to lower fuel and maintenance costs.*
>
> *— Gara Hay, President, MTB Transit Solutions*

10. Training

10.1 Training Drivers

High Level

A Natural Resources Canada (NRCan) survey uncovered that 66% of Canadians have never ridden in or driven a zero-emission vehicle before.[45] Therefore, it is not unreasonable to suggest that many drivers in the transportation sector also have no experience driving a zero-emission vehicle. Although the basic principles remain the same, there are a few nuanced specifics to share and learn about operating a zero-emission vehicle that may differ from a traditional petroleum diesel truck.

Drivers should be given a basic education about the different vehicle types, operational differences of new vehicle technologies compared to traditional diesel trucks, and specific information related to the type of ZEV to be incorporated into fleet operations. This includes understanding electric drive systems and how to drive and operate them most efficiently, battery management and optimal charging strategies, hydrogen fuel cell refueling and safety training, and the differences between biodiesel and HDRD fuel systems as well as when to fuel with what type of alternative fuel according to seasonal patterns.

Tell Me More

BEV

Drivers should be trained in energy-efficient driving techniques, including maximizing regenerative braking, understanding range implications, and efficient acceleration and deceleration practices.

45 | Natural Resources Canada (2021) 'Canadians' Awareness, Knowledge and Attitudes Related to Zero-Emission Vehicles (ZEVs)'. Available at: https://natural-resources.canada.ca/sites/nrcan/files/057-21-NRCan_ZEVs_Final_Report_EN_accessible.pdf (Accessed: 12 March 2024).

Drivers should be familiar with charge time implications and understand the time requirements for charging the vehicle they are operating. This information is available from the OEM and should be made available in accessible locations, including within the vehicle itself.

MHDZEV dealers and manufacturers provide some driver training, but this is not standardized across the industry. Training and testing should be addressed as soon as the vehicles and chargers are delivered and installed to ensure safe deployment of vehicles.

FCEV

FCEVs involve charging using high pressured gas systems: either 350 or 700 bar. Safety protocols around HFC vehicles is an essential issue to address via training on high-pressure storage system refueling.

PHEV and Hybrids

Like the adjustment in electric vehicle driving, PHEV and hybrid vehicle drivers should understand energy-efficient driving techniques, including maximizing regenerative braking, understanding range implications, and efficient acceleration and deceleration practices. Inform drivers about the type of vehicle that they are operating, understanding that PHEV must be plugged in to recharge the battery pack, while hybrid vehicles are charged simply through regenerative braking.

Alternative Fuels

Biodiesel may provide a slightly different torque response due to its higher cetane number, which can affect acceleration characteristics. Training should also cover operational changes related to fuel characteristics, especially in terms of how biodiesel and HDRD handle different weather conditions.

Biodiesel has a tendency to gel in cold temperatures, which could impact fuel flow and vehicle operation. Drivers should be trained on recognizing the signs of fuel gelling and understand the importance of using winterized biodiesel blends or additives to enhance cold flow properties. Finally, it's important for drivers to be informed about the availability of these fuels, especially if operating routes where biodiesel or HDRD might not be readily available.

10.2 Training Facility Management Teams

Shifting towards zero-emission vehicle technologies in MHDVs requires competent facility management operators. As thoughtful infrastructure updates and deployment play an important role in the success of zero emission and low-carbon fleet deployment, having facility operators possess the skills to maintain and manage new infrastructure such as charging stations and hydrogen refueling equipment.

For charging equipment, facility managers should be aware of technical and permitting requirements for the required charging infrastructure (level 2, DC fast chargers, etc.) and ensure they are kept in optimal working condition. This includes a regular inspection schedule, checking for wear on critical components, and maintaining clean components. Facility managers should follow OEM specifications, including following any available OEM operation manuals, specialized training resources and outlined diagnostic strategies for trouble shooting.

Facility mangers should understand hydrogen refueling systems and provided adequate training for safe handling and understand leak detection procedures. As with charging infrastructure, any new piece of infrastructure equipment should follow an inspection and maintenance schedule to maintain the infrastructure integrity and operability.

10.3 Training Maintenance Workers

High Level

Training maintenance workers is crucial to preparing MHDV fleet owners and operators to transition to zero-emission vehicles. This involves providing specialized training on maintaining and repairing all varieties of zero-emission and low-carbon vehicles. Further, new capabilities are required to accommodate new infrastructure maintenance and energy procurement. Staff should have adequate training to handle new energy systems, including high wattage charging systems or hydrogen fueling equipment. Organizations may need to assess gaps in skills and hire or train personnel accordingly.

Canadian-specific training courses and modules are being developed across the country, and more are expected to come online as more fleets transition to ZEVs. In the meantime, fleet operators should consult with the vehicle OEMs and dealerships for specific maintenance requirements and instructions.

Tell Me More

BEV Maintenance

Although EV maintenance is generally lower than the required engine servicing for diesel-powered engine trucks, there are some other nuances, including:

- **Tire Wear:** On average, EV trucks are heavier than their incumbent diesel-powered trucks, which could have the knock-on effect of wearing the tread on the vehicle's tires faster.

- **Battery Capacity Decline and Cold Weather Performance:** Technicians should be aware that battery capacity, as with any lithium-ion battery, will degrade over time and may have reduced performance (range).

- **Software Updates and Vehicle Prepping:** EVs require regular software updates for the vehicle's operating system and diagnostic checks for electric drive units and battery management systems. These are typically done over the air (OTA) automatically on a regular basis. Having wi-fi availabl where vehicles are parked for charging or overnight storage can help with updates. Otherwise, these can be done before the truck is deployed and still charging to ensure the vehicle is fully charged and optimized for the day's duty cycle.

- **Inspection of Charging Equipment:** Technicians should inspect charging cables and connectors for any signs of damage or wear to prevent faulty charging.

- **Battery Coolant:** Although EVs produce considerably less heat than an ICE vehicle, many models of EVs recommend coolant to ensure battery capacity lasts longer. Check with the OEM specifications of the vehicle as some recommend specific low conductive coolant to be used.

- **High-Voltage Electrical Safety Training:** Some OEMs and other organizations provide specific high-voltage electrical safety courses for technicians. These courses ensure that technicians adhere to best practices, standards and frameworks for handling electrical hazards and working safely. Uncertified personnel should never be expected to handle high voltage.

FCEV Maintenance

There are limited dedicated training programs for FCEMHDV maintenance. This should change, and more should become available as hydrogen becomes an important component of the Canadian energy ecosystem.

There are a few varieties of hydrogen-powered vehicles, so technicians need to understand which vehicle type they are dealing with. After the creation of electricity from hydrogen, FCEVs behave similarly to electric vehicles, and do not have any moving engine components like those found in ICE trucks.

With that understanding, we can see a few issues specific to FCEVs that should be considered.

- **Cathode Air Filter Checks:** As noted above, clean air is essential for the fuel cell's operation. The cathode air filter must be regularly inspected and replaced at OEM-recommended intervals to prevent clogging and ensure an adequate supply of clean air to the proton exchange membrane PEM.

- **Electrolyte Fluid Check:** Ensure the proper level of electrolyte fluid is available for the vehicle to function normally.

- **High-Pressure Storage Inspection:** FCEVs store hydrogen at high pressures (up to 700 bar), necessitating regular inspections of the storage tanks and related high-pressure components for any signs of stress, damage, or leaks. Inspections of storage components should follow manufacturer guidelines to ensure the integrity of the storage system and minimize the risk of leakage.

- **High-Pressure Safety Training and Equipment:** Technicians should be trained in handling hydrogen safely, understanding the risks associated with high-pressure systems, and knowing how to respond to hydrogen-related emergencies.

Biodiesel Maintenance

While most OEMs state that blends up to B20 can be maintained without any further attention or details, there are some nuances and factors to be aware of when using biodiesel blends higher than B20. Additionally, fleet owners should check with their OEM warranties, as some OEMs do not approve the use of blends greater than B20 in their vehicles; in these cases, their use could void the new vehicle's limited warranty.

- **Degradation of Rubber Components:** Biodiesel blends higher than B20 have been reported to degrade rubber, so any seals or hoses in the fuel system that are made of rubber will be susceptible to damage. Technicians should take extra care in inspecting rubber components to make sure they are in working order.

- **Filter Clogging:** Fuel filter clogging leads to difficult cold weather starts, an issue that can be mitigated by scheduling more frequent maintenance intervals to ensure clean filters. It is also recommended not to let vehicles sit with biodiesel for long periods (greater than a month). This will help prevent the fuel filter clogging and potential damage to the fuel injection system due to degraded biodiesel.

HDRD Maintenance

HDRD is a drop-in replacement for petroleum diesel and is chemically almost identical to the incumbent fuel it is replacing. Maintenance of vehicles using HDRD should follow a regular maintenance schedule consistent with that of a petroleum diesel engine truck.

PHEV and Hybrid Maintenance

PHEV and hybrid vehicles have both electrical motor and ICE components, requiring attention to both systems.

- **ICE Components:** Regular maintenance of both dry and wet service schedules can be followed on the ICE side.

- **Battery Specific:** Additional requirements for maintenance should inspect the hybrid battery health, the inverter cooler, the regenerative braking system and the inspection of the charge port on PHEVs.

Additional Resources

As zero-emission transportation gains momentum across Canada, new programs are being developed to support the maintenance and operation of these technologies. Many training modules are currently geared towards light-duty vehicles, reflecting the initial wave of electric vehicle adoption. However, as demand for ZEMHDV grows, it is anticipated that more resources tailored to these larger vehicles will become available. In the interim, consulting with the vehicle's OEM is advisable, as they provide training and resources with the most up-to-date and vehicle-specific requirements.

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Additional Resources

- **Electric Autonomy Canada Driver Onboarding and Training**
  Resources provided by Electric Autonomy Canada. Covers charging and battery management, driving habits, and understanding electric vehicles. Information is specific to EV fleet transition.

- **Canada Training Group High Voltage Electrical Safety Course for Battery Electric Vehicles**
  These courses cover a wide array of topics, including low/high voltage maintenance, grounding, battery maintenance, and troubleshooting.

- **Kenworth EV Technician Training and Certification Program**
  Kenworth launched a program to provide training and certification for technicians on service systems, electrical principles, electrical systems, electrical systems II, cab and chassis electronics, electric vehicles systems, and advanced electric diagnostics.

- **Red River College Polytechnic Hydrogen Fuel Cell Vehicles Micro-Credit Course**
  This tuition-free Hydrogen Fuel Cell Vehicles micro-credit course, provides instruction on understanding how hydrogen is produced and stored, safety concerning high-pressure hydrogen storage systems and information on servicing needs of HFC vehicle systems.

11. Monitor and Report on Performance and Cost

Regular monitoring of essential metrics enables fleet operators to stay adaptable and modify their strategies to ensure they meet their objectives.

11.1 Establishing a Baseline and Developing Indicators

Establishing a baseline and developing key performance indicators (KPIs) is important for effective performance tracking and management. This foundation enables fleet operators to measure progress, identify areas for improvement, and make data-driven decisions. Regular reporting and in-depth analysis of collected data are essential for understanding fleet performance, making informed decisions, and communicating progress to stakeholders.

Fleet operators should begin by establishing a baseline to monitor current fleet performance, including metrics such as fuel consumption, maintenance costs, vehicle uptime, and emissions. Following this, develop specific, measurable indicators tailored to your fleet's operational goals and the unique aspects of your alternative fuel vehicles. These indicators might include energy consumption per km, cost per km, uptime percentages, and greenhouse gas emissions reduction. Set realistic and measurable targets for each KPI, considering industry benchmarks and your fleet's historical performance. Regularly reviewing these indicators will help you gauge your fleet's progress towards its goals and identify areas for improvement.

Develop a structured reporting framework that includes regular intervals for data collection, analysis, and dissemination of findings. Reports should be clear, concise, and tailored to the needs of different stakeholders, including management, operational staff, and external partners.

Incorporate data visualization tools and dashboards to present information in an easily understandable format. Analyze the data to identify patterns, compare performance against targets, and draw insights. Use these insights to refine operational strategies, enhance efficiency, and scale your alternative fuel deployment effectively.

11.2 Monitoring Telematics, Operational and Cost Data

Continuous monitoring of telematics, operational, and cost data is vital to understand the real-time performance of your fleet and the efficiency of your alternative fuel deployment. This data can be used to scale your deployment cost-effectively.

Leverage telematics systems to collect data on vehicle location, energy usage (or fuel consumption for non-electric vehicles), driving patterns, and refueling or charging events. Combine this with operational data, such as vehicle availability, load capacity, and route completion rates, alongside cost data, including fuel or electricity costs, maintenance expenses, and total cost of ownership.

Use this comprehensive dataset to monitor your fleet's performance against established KPIs. Analyzing this data will help identify trends, pinpoint inefficiencies, and uncover opportunities for cost savings and operational improvements across different fuel technologies. In-depth monitoring can enable the establishment of preventive maintenance approaches and optimization of fuel or energy consumption.

For battery electric vehicles, specifically, close monitoring of the real-time performance during small-scale pilot deployments is crucial. It allows you to understand the capabilities of the technology under your specific local conditions. This understanding can guide you to plan your larger deployment in the most cost-effective manner by avoiding overdesign, such as purchasing vehicles with larger battery sizes than necessary or building larger-than-necessary charging infrastructure. This principle can extend to other technologies by tailoring infrastructure and vehicle specifications to actual needs, such as the appropriate capacity for hydrogen fuel storage or the optimal blend of biodiesel or HDRD, thereby ensuring that the deployment is both efficient and cost-effective.

In the context of alternative fuel technologies, whether battery electric, hydrogen fuel cell, biodiesel, or HDRD, it is critical to pilot different vehicles and infrastructure types. Closely monitor their performance under your specific local conditions before scaling. This approach allows for informed decisions that consider the unique requirements and benefits of each alternative fuel technology, ensuring that your deployment is tailored to your operational needs and environmental goals.

11.3 Reporting and Analysis of Data

Transitioning from the collection of performance and operational data, the aim will be to transform this data into actionable insights. By using the captured data from pilot phases and ongoing operations, areas of improvement can be understood, thereby informing future strategies for wider and more effective ZEV adoption.

Consider developing a **lessons learned and best practices** document. This information is useful for scaling up ZEV adoption and for guiding future projects internally to avoid any major pitfalls. If the document is made publicly available, it can support adoption efforts more broadly within the transportation industry.

By effectively reporting and analyzing data, organizations can make informed decision making and ensure that their move towards zero-emission fleet operations is not only strategic but also aligned with broader objectives. This continuous loop of performance tracking, reporting, and analysis is essential for the adoption of ZEMHDVs.

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Additional Resources

- **Pollution Probe (2023), Electric School Bus Demonstration**
  The project involved monitoring the energy usage of an electric school bus in different conditions, evaluating how weather and regenerative braking affect its range. It also examined the cost implications of these factors. Retrieved from:

- **NACFE (2022), Electric Trucks Have Arrived Documenting A Real-World Trucking Demonstration**
  The Run on Less – Electric demonstration showcased commercial battery electric vehicles under a number of applications. Data such as daily range, charging events, regenerative braking, and weather conditions were collected.

- **GEOTAB (2023), Building a Business Case for Adopting EVs and Sustainable Fleet Strategies**
  A guide for to help fleet owners outline their plan to reduce operating costs and carbon emissions through electrification.

Appendix A

Summary of Federal & Provincial Regulations & Policies

Jurisdiction	Regulation/Policy	Description and Scope	Date
Canada - Federal	Clean Fuel Regulation (CFR)	The CFR will cover liquid petroleum fuels used in Canada and will come into effect on July 1, 2023. The proposed Regulations will require liquid petroleum fuel primary suppliers (producers and importers) to reduce the carbon intensity of their fuels used in Canada from 2016 levels by 3.5 gCO2 e/MJ in 2023 increasing to a 14 gCO2 e/MJ reduction in 2030. Will achieve emission reductions from fuels used primarily in transportations. Will include flexible compliance options including increasing renewable fuel content, generating credits through fuel switching and using energy sources and technologies that displace petroleum fuels.	Came into effect July 1, 2023
	Carbon Price Backstop	The federal pricing system has two parts: the fuel charge or levy, and the Output-Based Pricing System. The government has released new benchmark criteria for 2023-2030, which sets out the carbon pricing increases. Provinces and territories will need to update their legislation to reflect the new minimum carbon prices to retain equivalency for 2023 and beyond. 2019: $20 2023: $65 2027: $125 2020: $30 2024: $80 2028: $140 2021: $40 2025: $95 2029: $155 2022: $50 2026: $110 2030: $170	Came into effect October 23, 2018

Jurisdiction	Regulation/Policy	Description and Scope	Date
	Hydrogen Strategy for Canada	In Dec 2020, the Federal Government released a national Hydrogen Strategy under the leadership of NRCan. The Strategy focuses on building new hydrogen supply and distribution infrastructure and uptake in end-uses.	Came into effect July 1, 2023
	Carbon-Pollution Regulations for Heavy-Duty Vehicles	ECCC introduced carbon-pollution regulations for heavy-duty vehicles that began in January 1, 2020 and will become increasingly stringent. Regulations will target school buses, transport tractors and trailers, garbage trucks, delivery vans, and larger pick-up trucks. The regulations are intended to reduce $1.7 billion in fuel costs for new vehicle owners annually. The regulations are intended to promote innovation and provide flexibility to industry to choose the most cost-effective compliance options.	Came into effect October 23, 2018
British Columbia	Carbon Tax	Provincewide carbon tax of $45 per tonne on petroleum fuels including gasoline, natural gas and diesel. The carbon tax will increase to $50 per tCO2e in April 2022.	Came into effect July 1, 2008
	Renewable & Low Carbon Fuel Requirements Regulation	Upon the release of the CleanBC Report, the LCFS has been increased to 20% reduction in carbon intensity by 2030.	First applied as the Greenhouse Gas Reduction (Renewable and Low Carbon Fuel Requirements) Act (GGGRA) in 2010 replaced by: Low Carbon Fuels Act, came into effect January 1, 2024

Jurisdiction	Regulation/Policy	Description and Scope	Date
	Climate Change Accountability Act	BC's current target is 16% below 2007 levels by 2025, and the province has legislated emission targets for 2030, 2040 and 2050 of 40%, 60% and 80% below 2007 levels, respectively.	Came into effect June 1, 2018
	BC Hydrogen Strategy	BC's Hydrogen Strategy sets out short-, mid-, and long-term actions to increase production and use of hydrogen. Hydrogen is projected to deliver 11% of their emissions reductions to 2050, particularly in sectors where electrification is not practical, including transportation. A set of 63 actions are set out in the strategy, with a subset dedicated to supporting growth in transportation use. Specific actions of note: • Piloting hydrogen fuel cells for medium and heavy-duty transportation, with an action to support widespread use beyond 2030 • Provide incentives for vehicle purchases and fueling infrastructure • Establish targets for medium and heavy-duty vehicles under the ZEV act	Released July 7, 2021
	Weight allowance for low-carbon commercial vehicles	In 2021, BC announced a new weight allowance for low-carbon commercial vehicles. BC will provide a 1500 kg allowance to electric full sized commercial vehicles and a 1000 kg allowance to hydrogen-powered vehicles. The purpose is to offset the loss in payload capacity that operators face due to the heavier weight of these vehicles compared to diesel.	Came into effect May 14, 2021
Alberta	Natural Gas Strategy	The 2020 Natural Gas Strategy focuses on large-scale hydrogen production with carbon capture, utilization and storage (CCUS) and deployment in various commercial applications across the provincial economy by 2030. Exports of clean hydrogen and hydrogen-derived products to jurisdictions across Canada, North America, and globally are in place by 2040.	Released October 6, 2020

Jurisdiction	Regulation/Policy	Description and Scope	Date
	Hydrogen Roadmap	The 2021 Hydrogen Roadmap covers market opportunities identified within Alberta including electricity generation and storage and transportation.	Released November 5, 2021
	Renewable Fuel Standard	The RFS requires a minimum annual average of 5% renewable alcohol in gasoline and 2% HDRD in diesel fuel sold in Alberta by fuel suppliers. To meet the RFS, renewable fuels must demonstrate at least 25% fewer GHG emissions than the equivalent petroleum fuel.	Came into effect January 2008
Saskatchewan	Federal fuel charge	Saskatchewan released its carbon management plan on Dec 4, 2017. It includes direct regulation in the areas of natural systems, physical infrastructure, economic sustainability, community preparedness, and measuring, monitoring, and reporting.	Came into effect December 4, 2017
Manitoba	The Climate and Green Plan Implementation Act	The biodiesel content of diesel was amended to 3.5% for the 2021 reporting period, and to 5% in the 2022 reporting period and each reporting period after that.	Released in 2022
	Biofuels Act	The biodiesel content of diesel was amended to 3.5% for the 2021 reporting period, and to 5% in the 2022 reporting period and each reporting period after that.	Released in 2022
	Green Transportation Strategy	Manitoba's Expert Advisory Council (EAC) has issued a report to the government on Recommendations for A Green Transportation Strategy. Notable recommendations include: • Increase biofuels targets to 15% ethanol and 10% biodiesel • Support replacing heavy duty diesel vehicles with low carbon/ zero emission options • Collaborate with other levels of government and the private sector to encourage low carbon movement of goods • Encourage pilot projects and product testing through financial mechanisms and incentives • Develop a favourable tax regime for cleantech innovation and adoption	Released in June 2021

Jurisdiction	Regulation/Policy	Description and Scope	Date
Ontario	Cleaner Transportation Fuels Regulation	Regulates that 4% of the total volume of diesel fuel must be bio-based. The bio-based diesel component of this blend must have 70% lower greenhouse gas emissions than standard petroleum diesel.	Updated November 25, 2020
Quebec	Bill 44: An Act to ensure effective governance of the fight against climate change and to promote electrification	Over the next five years, 3.6 billion dollars will be invested in the transportation sector, with a target of 1.5 million electric vehicles on Québec roads by 2030. It will further support the development of electric vehicles, charging infrastructure and batteries, along with $213 million for the emerging renewable natural gas sector and $15 million for innovation in the green hydrogen sector. The 2021-2026 implementation plan for the 2030 Plan for a Green economy has been released.	Came into effect November 1, 2020
	Low-carbon Intensity Fuel Standard	In December 2021 Quebec published final regulations covering integration of low-carbon intensity fuel content into gasoline and diesel. The regulation requires distributors to meet 15% low-carbon-intensity fuel in gasoline and 10% in diesel by 2030. A system for sale and trade of credits will be established. A distributor is a manufacturer or importer that supplies a wholesaler or retailer liquid fuel or retails liquid fuel in Quebec. Integration standards: Gasoline: 10% by 2023, 12% by 2025, 14% by 2028, 15% by 2030 Diesel: 3% by 2023, 5% by 2025, 10% by 2030	Came into effect January 1, 2023
	Hydro Quebec Hydrogen Strategy	Quebec Hydro is planning on producing hydrogen through electrolysis rather than from the methane in natural gas.	Released December 8, 2020
New Brunswick	New Brunswick's output-based pricing system	In line with the federal approach, the provincial plan will apply to 20 separate fuels, while allowing the NB government to determine how revenues will be recycled.	Came into effect January 1, 2021

Jurisdiction	Regulation/Policy	Description and Scope	Date
Nova Scotia	Environmental Goals and Climate Change Reduction Act	Nova Scotia has introduced legislation with new provincial climate and sustainability targets. The Environmental Goals and Climate Change Reduction Act will establish an emissions reduction target for the province of 53% below 2005 levels by 2030 and net-zero by 2050. To achieve these targets the Act introduces new goals related to renewable energy, buildings, conservation, waste, and air quality.	Came into effect November 5, 2021
	Nova Scotia's Output-based Pricing System for Industry	The Output-based Pricing System will regulate greenhouse gas emissions from large emitters. Participation in the Output-based Pricing System is limited to Nova Scotian facilities engaged in (i) manufacturing and processing; (ii) mining, quarrying, and oil and gas extraction; or, (iii) electricity generation.	Came into effect January 1, 2023
Northwest Territories	Carbon Tax	The carbon tax minimizes the impacts on households and businesses through rebates. Prices align with the federal benchmark ($20 in 2019 rising to $50 in 2022). The tax applies directly to any fuel sold in the territory, and costs trickle down to affect almost all goods and services.	Came into effect September 1, 2019

Appendix B

Summary of Federal & Provincial Incentives (Fall 2024)

Location	Funding Organization	Fund Name	Description	Date
Canada	Transport Canada	Incentives for Medium- and Heavy-duty Zero-Emission Vehicles (iMHZEV) Program	Incentives for purchase of lease of new ZEMHDV. Incentives range from $25,000 for a 12-month lease, to $200,000 for a 48-month lease or purchase of the vehicle, depending on vehicle type, make and model. UPDATE: As of October 1, 2024, only zero-emission vehicles (ZEVs) that are made in Canada or in countries with which Canada has a free-trade agreement, may be eligible under the Incentives for Medium- and Heavy-Duty Zero-Emission Vehicles (iMHZEV) Program.	Launched in July 2022 – Available until March 31, 2026
Canada	Transport Canada	Zero Emission Vehicle (ZEV)	100% tax write-off for ZEVs to support business adoption, including MHD.	
Canada	NRCan	Zero Emission Vehicle Infrastructure Program (ZEVIP)	Funding for electric vehicle charging and/or hydrogen infrastructure for corporate fleets, last-mile delivery fleets, and mass transit.	Launched on March 2, 2020 – Available until 2027
Canada	Infrastructure Canada	Zero Emission Transit Fund	Funding for public transit systems for the purchase of ZE buses and related infrastructure.	Launched in August 2021 – Available until 2026

Location	Funding Organization	Fund Name	Description	Date
Canada	Infrastructure Canada	Rural Transit Solutions Fund	Funding for ZE transit solutions including the purchase of zero emission vehicles	Launched in 2021 – Available until funds are exhausted
Canada	Canadian Infrastructure Bank (CIB)	N/A	Funding for ZE public buses and infrastructure.	No date mentioned
BC	Provincial Government	CleanBC Go Electric Program - Commercial Vehicle Pilots (CVP) Program	Funding to accelerate adoption of commercial ZEVs including MHDV.	Launched in October 2021 – Available until funds are exhausted
BC	BC Ministry of Transportation and Infrastructure + BCTA	Heavy-duty Vehicle Efficiency Program	Rebates of up to 50 percent of costs for eligible equipment, to a maximum of $15,000 per vehicle or $100,000 per fleet, as part of the CleanBC Heavy-duty Vehicle Efficiency Program.	Launched in October 2019 – Available until August 2025 or until all funds have been exhausted.
BC	Plug In BC	CleanBC Go Electric Rebates (formerly SUVI)	Rebates of up to 33% of the vehicle MSRP for purchase or lease of MHDV.	Launched in 2011 as the Speciality Use Vehicle Incentive (SUVI) program and has expanded since to include MDHV

Location	Funding Organization	Fund Name	Description	Date
BC	CleanBC	CleanBC Go Electric Medium- and Heavy-Duty Public Charger Program	Provides rebates for public fast chargers to support MHD vehicles.	Current funding call opened August 1, 2024 and will run until November 29, 2024
Nova Scotia	EV Assist	Electrify Nova Scotia MHZEV Rebate Program	Rebates for MHZEV, provided for the purchase or lease of qualifying MHZEV. Funds are provided on a first-come, first-served basis until exhausted.	Launched on April 1, 2024 – Available until funds are exhausted
Quebec	Transition Énergétique Quebec	Transportez vert	Funding available to support eco friendly driving (écoconduite) workshops for MHDV (50% of workshop cost up to $1,000 per workshop).	Launched on July 19, 2019 – Available until funds are exhausted

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